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VORTEX-LATTICE FORTRAN PROGRAM FOR ESTIMATING SUBSONIC AERODYNAMIC CHARACTERISTICS OF COMPLEX PLANFORMS

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16. Abstract

A computer program has been developed for estimating the subsonic aerodynamic characteristics of complex planforms. The program represents the lifting planform with a vortex lattice. This paper is intended as a user's guide and includes a study of the effect of vortex-lattice arrangement on computed results, several sample cases, and a listing of the FORTRAN computer program.

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SUMMARY

A FORTRAN computer program has been developed for estimating the subsonic aerodynamic characteristics of complex planforms. The program represents the lifting planforms with a vortex lattice. These complex planforms include wings with variable-sweep outer panels, wings with several changes in dihedral angle across the span, wings with twist and/or camber, and a wing in conjunction with either a tail or a canard. The aerodynamic characteristics of interest are lift and pitching moment for both the flat and/or twisted wing, drag-due-to-lift parameter, leading-edge thrust, leading-edge suction, distributions of leading-edge thrust and suction coefficients, distributions of several span loading coefficients, distribution of lifting pressure coefficient, damping-in-pitch parameter, damping-in-roll parameter, and lift coefficient due to pitch rate.

This paper is intended as a user's guide for program application and sample cases are included to illustrate most of the options available for use in the program. Also included is a study of the effect of the vortex-lattice arrangement on some of the computed aerodynamic characteristics along with some recommendations for specifying vortex-lattice arrangements for particular types of planforms.

INTRODUCTION

In recent years, some wings have become very complex because of the varied speed regimes in which they are required to operate. Such wings may have variable sweep, several changes in dihedral angle across the span, or even a variable dihedral angle near the wing tip. Computing procedures for predicting the aerodynamic characteristics of these wings become very involved if an adequate representation of the planform is to be made. The problem becomes more involved when the body or body and tail are included in the representation. In order to solve this problem for preliminary designs or for parametric evaluations, a computer program has been developed for estimating the aerodynamic characteristics of these complex planforms.

In this FORTRAN computer program, the planform in steady subsonic flow is represented by a vortex lattice. Although this type of representation is not new (for example, refs. 1 to 12), the present program has several useful features that are not found together in other generally available programs of either the vortex-lattice or pressure-doublet type (refs. 13 to 15).

The program uses a minimum of input data to describe relatively complex planforms. These planforms may be described by up to 24 line segments on a semispan. They may have an outboard variable-sweep panel or they may have several dihedral angles across the span. In addition, two planforms may be used together to represent a combination of wings and tails or wing, bodies, and tails. The analysis in the present paper has been extended to handle planforms in a sidewash field. These velocities occur when a planform has dihedral or when a second planform is placed at a different height from the first planform.

The program described in the present paper was developed from a basic program written several years ago, which has had considerable use at the Langley Research Center. In recent years this basic program has also been used in industry. The results have shown good correlation with experimental data.

The present paper is intended to serve both as a description of the program and as a user's guide for its application. This paper describes in detail the program input data (appendix A) and output data (appendix B) and provides examples and typical running times of various types of configurations which can be handled (appendix C) along with a FORTRAN program listing (appendix D). In addition, the results of parametric applications of this program are presented to provide guidance in specifying vortex-lattice arrangements which can be expected to give acceptable results.

SYMBOLS

The geometric description of planforms is based on the body-axis system with the origin on the planform center line. (See fig. 1 for positive directions.) The planform is replaced by a vortex lattice which is in a wind-axis system with the origin in the planform plane of symmetry. (See sketch (d) in text for details.) The axis system by which the geometric influence of a given horseshoe vortex is computed is wind oriented and referred to the origin of that horseshoe vortex (fig. 1). The units used for the physical quantities defined in this paper are given both in the International System of Units (SI) and in the U.S. Customary Units. For the purpose of the computer program, the length dimension is arbitrary for a given case; angles associated with planform are always in degrees. The symbols used for input data in the computer program are described in appendix A. The symbols used in the description of the program are defined as follows:

A	aspect ratio; listed as AR in computer program output
B_k	element of boundary-condition matrix, $4\pi\alpha_k$
b	wing span, m (ft)
$C_{D,i}$	induced drag coefficient, $\dfrac{\text{Induced drag}}{q_\infty S_{ref}}$
$C_{D,i}/C_L^2$	induced drag parameter based on Munk's far-field solution
$C_{D,ii}/C_L^2$	induced drag parameter based on near-field solution
C_L	lift coefficient, $L/q_\infty S_{ref}$
$C_{L,\tau}$	lift coefficient based on additional loading and actual planform area
C_{L_q}	lift coefficient due to pitch rate, $\dfrac{\partial C_L}{\partial\left(\dfrac{qc_{ref}}{2U}\right)}$, per rad
C_{L_α}	lift-curve slope, $\left(\dfrac{\partial C_L}{\partial \alpha}\right)_o$, per deg or per rad
C_l	rolling-moment coefficient, $\dfrac{\text{Rolling moment}}{q_\infty S_{ref} b}$
C_{l_p}	damping-in-roll parameter, $\dfrac{\partial C_l}{\partial\left(\dfrac{pb}{2U}\right)}$, per rad
C_m	pitching-moment coefficient about $\hat{Y}$-axis, $\dfrac{\text{Pitching moment}}{q_\infty S_{ref} c_{ref}}$
$\partial C_m/\partial C_L$	longitudinal stability parameter
C_{m_q}	damping-in-pitch parameter, $\dfrac{\partial C_m}{\partial\left(\dfrac{qc_{ref}}{2U}\right)}$, per rad
C_n	element of circulation term matrix, Γ_n/U

ΔC_p	incremental pressure coefficient, $\dfrac{p_{lower} - p_{upper}}{q_\infty} = \dfrac{\Delta p}{q_\infty}$
C_S	leading-edge suction coefficient, $\dfrac{\text{Suction}}{q_\infty S_{ref}}$
C_T	leading-edge thrust coefficient, $\dfrac{\text{Leading-edge thrust}}{q_\infty S_{ref}}$
c	chord, m (ft)
c_{av}	average chord, S_T/b, m (ft)
c_c	chord along left trailing leg of elemental panel, m (ft)
$c_{d,ii}$	section induced drag coefficient based on near-field solution
c_l	section lift coefficient
c_{ref}	reference chord, m (ft)
c_s	section leading-edge suction coefficient
c_t	section leading-edge thrust coefficient
d_{ii}	section induced drag based on near-field solution, N/m (lb/ft)
F	influence function which geometrically relates influence of single horseshoe vortex to a quantity which is proportional to velocity induced at a point, m^{-1} (ft^{-1})
$\overline{F}$	sum of influence function F at a control point on wing caused by two symmetrically located horseshoe vortices, one on left half of wing and one on right half of wing, m^{-1} (ft^{-1})
$G_{n,k}$	element of influence function matrix, $\overline{F}_{w,n,k} - \overline{F}_{v,n,k} \tan \phi_n$
L	lift for entire wing, N (lb)
l	lift per unit length of span, $\hat{l}/(2s \cos \phi)$, N/m (lb/ft)

$\tilde{l}$ lift per unit length of vortex filament, N/m (lb/ft)

$\hat{l}$ lift generated along a finite length of vortex filament, N (lb)

M_Y pitching moment for entire wing about $\hat{Y}$-axis, m-N (ft-lb)

M_∞ free-stream Mach number

m_Y pitching moment about $\hat{Y}$-axis due to lift developed on elemental panel, m-N (ft-lb)

N maximum number of elemental panels on entire wing

$\overline{N}_c$ number of elemental panels in a chordwise row

$\overline{N}_s$ number of chordwise rows of elemental panels on wing semispan

p roll rate, rad/sec; also, pressure, N/m^2 (lb/ft^2)

q pitch rate about $\hat{Y}$-axis, rad/sec

q_∞ free-stream dynamic pressure, N/m^2 (lb/ft^2)

S_{ref} reference area, m^2 (ft^2)

S_T actual planform area, m^2 (ft^2)

s horseshoe semiwidth in plane of horseshoe vortex, m (ft)

$T = S_{ref} \Big/ \left(2s_n \cos\phi \; c_{av}\right)$

t section leading-edge thrust per unit span, N/m (lb/ft)

U free-stream velocity, m/sec (ft/sec)

u backwash velocity, m/sec (ft/sec)

V resultant velocity, m/sec (ft/sec)

v sidewash velocity, m/sec (ft/sec)

w downwash velocity, m/sec (ft/sec)

X,Y,Z axis system of a given horseshoe vortex (see fig. 1)

$\bar{X},\bar{Y},\bar{Z}$ body-axis system for planform (see fig. 1)

$\hat{X},\hat{Y},\hat{Z}$ wind-axis system

x,y,z distance along X-, Y-, and Z-axis, respectively, m (ft)

$\bar{x},\bar{y}$ distance along $\bar{X}$- and $\bar{Y}$-axis, respectively, m (ft)

$\hat{x},\hat{y},\hat{z}$ distance along $\hat{X}$-, $\hat{Y}$-, and $\hat{Z}$-axis, respectively, m (ft)

$\bar{x}_{c/4}$ midspan $\bar{x}$-location of quarter-chord of elemental panel, m (ft)

$\bar{x}_{3c/4}$ midspan $\bar{x}$-location of three-quarter-chord of elemental panel, m (ft)

$x' = x/\beta$

y_{cp} fractional spanwise distance from root chord to center of pressure on left wing panel

α angle of attack, deg

α_i induced angle of attack, rad

β Prandtl-Glauert correction factor to account for effect of compressibility in subsonic flow, $\sqrt{1 - M_\infty{}^2}$

Γ vortex strength, m^2/sec (ft^2/sec)

γ nondimensional lift, $\dfrac{\Gamma}{bU}$ or $\dfrac{c_l c}{2b}$

$\Delta\Gamma$ net vortex strength along left trailing leg of elemental panel, m^2/sec (ft^2/sec)

η nondimensional spanwise coordinate, $\hat{y}/(b/2)$

ρ	density, kg/m^3 $(slugs/ft^3)$
ϕ	dihedral angle, in $\bar{Y}$-$\bar{Z}$ plane, deg
Λ	planform leading-edge sweep angle, in $\bar{X}$-$\bar{Y}$ plane, deg
ψ	quarter-chord sweep angle of elemental panel; because of the small angle assumption, also used as sweep angle of spanwise horseshoe vortex filament, in X-Y plane, deg

$\psi' = \tan^{-1}((\tan \psi)/\beta)$

Subscripts:

a	additional; or angle of attack
B	twist and/or camber at $C_L = 0$ for chordwise row of elemental panels
b	twist and/or camber at $C_L = 0$ for elemental panel
d	desired
i	index for elemental panel in chordwise row
j	maximum number of elemental panels in chordwise row
k	index for control point
l	left half of wing
lower	lower surface
n	index for elemental panel on wing semispan
o	value taken at $C_L = 0$
r	right half of wing
rad	per radian angle of attack

s	spanwise bound vortex element
t	chordwise bound vortex element
tc	twist and/or camber
u	backwash
upper	upper surface
v	sidewash
w	downwash

BASIC CONCEPTS AND LIMITATIONS

The vortex-lattice method is used in this computer program to determine the aerodynamic characteristics of planforms at subsonic speeds. This method is an extension of the finite step lifting-line method originally described in reference 16 and applied in reference 11. This method assumes steady, irrotational, inviscid, incompressible, attached flow. The effects of compressibility are represented by application of the Prandtl-Glauert similarity rule to modify the planform geometry. Potential flow theory in the form of the Biot-Savart law is used to represent disturbances created in the flow field by the lift distribution of the planform. It is assumed that in any plane parallel to the $\hat{X}$-$\hat{Z}$ plane the vertical displacements which occur in the wing or wake are neglected, except when the boundary conditions at the control points are determined.

The planform is divided into many elemental panels. Each panel is replaced by a horseshoe vortex. This horseshoe vortex has a vortex filament across the quarter-chord of the panel and two filaments streamwise, one on each side of the panel starting at the quarter-chord and trailing downstream in the free-stream direction to infinity. Figure 1 shows a typical horseshoe-vortex representation of a planform. The boundary condition for each horseshoe vortex is satisfied by requiring the inclination of the fluid streamlines to match the angle of attack at the three-quarter-chord point of its elemental panel. The circulations required to satisfy this tangent flow boundary condition is then determined by solving a matrix equation. Then, the Kutta-Joukowski theorem for lift from a vortex filament is used to determine the lift from each elemental panel. These lift results are then summed appropriately to obtain lift, pitching moment, and other aerodynamic characteristics. A similar procedure called the near-field solution is used to compute leading-edge thrust, suction, and induced drag. This program ignores the effect of thickness.

The lifting-surface planform is represented for the computer program by a series of up to 24 straight segments which are positioned counterclockwise around the perimeter of the left half of the planform. Lateral symmetry is presumed. The lines start at the leading edge of the plane of symmetry, go along the leading edge to the left tip of the planform, return along the trailing edge, and end at the trailing edge of the plane of symmetry. The preciseness of the $\bar{x}$ and $\bar{y}$ Cartesian coordinates and dihedral angles, given as input data, determines the accuracy of the planform representation. It is recommended that the planform coordinates listed in the second group of the geometry output data given in appendix B be plotted and examined after each computation to verify the accuracy of the planform representation. This check should be made before using the aerodynamic output data.

There are a number of restrictions and limitations in the application of this computer program. These limitations are discussed in detail in the program description and are noted with the appropriate input variables in appendix A. For the convenience of the program user, a complete list of restrictions and limitations is presented.

The restrictions in the first group apply to all planforms and are as follows:

(1) A maximum of two planforms may be specified. For examples, see sample case 1 for one planform and sample case 2 for two planforms.

(2) A maximum of 24 straight-line segments may be used to define the left half of a planform. The lateral separation of the ends of these lines can be critical when the horseshoe vortices are laid out by the computer program. For details of the lateral separation requirements, see pages 12 and 13.

(3) The maximum number of horseshoe vortices on the left side of the configuration plane of symmetry is 120. When two planforms are specified, the sum total of the vortices in both is limited to 120. Within this limit, the number of horseshoe vortices in any chordwise row may vary from 1 to 20 and the number of chordwise rows may vary from 1 to 50. For examples, see the sample cases in appendix C.

The limitations that apply only to variable-sweep planforms are (1) there should always be a fixed-sweep panel between the root chord and the outboard variable-sweep panel, (2) the pivot cannot be canted from the vertical, and (3) no provisions have been made for handling dihedral in the geometry calculations for the variable-sweep panel or at the intersection of this panel with the fixed portion of the wing.

The limitations that apply only to planforms which have nonzero dihedral angles or to two planforms which do not lie in the same plane are (1) the variation in local chord must be continuous from the tip chord to the root chord of each planform specified, (2) the number of horseshoe vortices in each chordwise row must be at least two, and (3) the number of horseshoe vortices must be constant over the semispan of each planform.

Restrictions on allowed values or codes for individual items of input data are described in appendix A.

The calculations presented herein were made with a computer which used approximately 15 decimal digits. For other computers with fewer significant digits, it may be necessary to use double precision for some of the calculations. In addition, it may be necessary to change some of the tolerances used in the program. These tolerances are mentioned in either the text or the program listing.

PROGRAM DESCRIPTION

This FORTRAN program is used to compute the following aerodynamic characteristics: C_{L_α}, C_L at $\alpha = 0$, α at $C_L = 0$, y_{cp}, C_{m_o}, $\partial C_m/\partial C_L$, $C_{D,i}/C_L^2$, $C_{D,ii}/C_L^2$, spanwise distribution of additional wing loading, spanwise distribution of wing loading due to twist and camber, and spanwise distribution of basic wing loading. In addition, the following aerodynamic characteristics are computed for a specified lift coefficient: the incremental pressure coefficient for each elemental panel, the spanwise distribution of the combined basic and additional wing loadings, the configuration angle of attack, and the contribution of the major planform to lift coefficient and induced drag coefficient. At an angle of attack of 1 rad, the induced drag, leading-edge thrust, and suction coefficients are computed for the entire configuration by using a near-field solution. This program can also be used to compute C_{l_p} or both C_{L_q} and C_{m_q} (rotary derivatives). These quantities are described in detail in Part III of the Program Description.

The computation in this program for the aerodynamic characteristics is divided into three parts: Part I contains the required geometric calculations, Part II contains the circulation term calculations, and Part III contains the final output terms, calculations, and answer listings. These three parts coincide with the three overlays in the FORTRAN computer program. The input data are described in detail in appendix A, and the output data are described in detail in appendix B. Several sample cases are given to illustrate the use of the program. Listings of the input data and computed results for these sample cases (appendix C), along with the FORTRAN computer program (appendix D) are given.

PART I – GEOMETRY COMPUTATION

The first part of the program is used to compute the geometric arrangement required to represent the planform by a system of horseshoe vortices and is divided into three sections. In Section 1, a description of the planform (group one of the input data in appendix A) is read into the computer. In Section 2, configuration details (group two of the input data) are read into the computer. In Section 3, the horseshoe vortex lattice is

laid out. When two planforms are used to describe a wing-body-tail configuration, each of these sections is repeated for the second planform. At the beginning of the geometry computation, a data card is read which describes the number of planforms (either 1 or 2), the number of configurations for which values are to be computed, and the reference values for chord and area.

Section 1. Reference Planform

The planform is described by a series of straight lines which are projected onto the $\overline{X}$-$\overline{Y}$ plane from the deflected planform as shown in figure 1 for a double-delta planform. The primary geometric data are the locations of the intersections of the perimeter lines, the dihedral angles, and an indication as to whether the lines are on a fixed or movable panel. The pivot location is also required for a variable-sweep planform. These data are described in group one of the input data (appendix A). For variable-sweep wings, the planform used for input should be the configuration with the movable panel in a position where the maximum number of lines required to form its perimeter are exposed.

Section 2. Configuration Computations

The particular configuration for which aerodynamic characteristics are sought is described by group two input data which are read here. These data include the following quantities: An appropriate configuration number, the number of horseshoe vortices chordwise, the nominal number of vortices spanwise, the Mach number, the particular lift coefficient at which the total span load distribution is desired, the sweep angle of the outboard panel for variable-sweep wings, a code to indicate whether C_{l_p} should be computed, a code to indicate whether C_{L_q} and C_{m_q} should be computed, and a code for each planform to indicate whether it is flat or whether it has twist and/or camber. The foregoing data are punched on one card for each configuration as described in appendix A.

The number of horseshoe vortices used in each chordwise row (SCW) can be constant across the span or it can vary. If it is constant, simply indicate the number on the configuration card and this value will be used on each planform of the group one input. If it varies, use 0 and add the required input cards to define the table of values (TBLSCW (I)) described in appendix A. However, it is usually desirable to use a constant value the first time a planform is used in the program. For all but the most simple planforms, the program adds some extra rows of horseshoe vortices. (This is described in Part I, Section 3.) As a result, the number of chordwise rows actually laid out (SSW) is usually greater than the nominal number of rows (VIC) and it takes one run through the program to determine the exact number and location of the rows.

The lift coefficient at which the total span load distribution (basic loading plus additional loading) is desired will usually be between 0 and 1. However, if a value of 11 is

specified, an induced drag polar is computed. In this case, the program will provide values of $C_{D,i}$ for 11 values of C_L from -0.1 to 1, as well as values of ΔC_p and the total span load distribution at a C_L of 1.

If a planform has twist and/or camber, additional data cards are required with the group two input data. These data are the local angles of attack in radians at the control points when the root-chord angle of attack is 0°. The control point of each elemental panel is at the midspan three-quarter-chord line. Generally, it is necessary to compute the vortex-lattice arrangement for the planform without twist and camber to determine the locations at which the local angles of attack are required. The order in which these data are provided is described in detail in appendix A. If a planform has no twist and/or camber, no additional cards are required for group two input twist data because the program will assign 0 for the values of the local angles of attack. If variations in the basic wing planform are desired for additional computer cases, they may be obtained by repeating only the group two input data with appropriate changes in any of the aforementioned variables.

For a variable-sweep planform, the angle which describes the sweep should be on the leading edge of the movable panel adjacent to the fixed portion. The intersection points and slopes for the planform in the desired position are then computed. For a fixed planform, the sweep-angle specification is not required because the program will use the unaltered basic planform. The planform breakpoints are checked to see whether any consecutive pair in the spanwise direction is less than (b/2)/2000 apart. If this occurs, the points are adjusted to coincide with each other. The adjustment is necessary to avoid a poorly conditioned matrix which could result in biased results for the circulation terms. Although this adjustment is usually adequate for planforms with no dihedral, it may not be sufficient for wings having dihedral or for use of this program in computers which have fewer than 15 significant decimal digits. This problem is discussed in detail in Part I, Section 3.

When two planforms are specified, the program compares the spanwise location of the breakpoints on both planforms inboard of the tip of the planform with the shorter semispan. If all the breakpoints coincide spanwise, no action is taken. However, if one planform has a breakpoint which does not occur on the other planform, an additional breakpoint is added to the other planform on its leading edge. This is done to force all trailing legs from the horseshoe vortices to occur at the same spanwise location, which keeps a trailing leg from one planform from passing close by a control point on the other planform and prevents unrealistic induced velocities at that control point.

The program determines the planform area and span projected to the $\overline{X}$-$\overline{Y}$ plane and uses these values to compute the average chord. Planforms which have a constant angle of dihedral from the root chord to the tip chord have an average chord which is independent

of dihedral angle. However, wings with more than one dihedral angle have an average chord which is dependent on the individual dihedral angles.

Section 3. Horseshoe Vortex Lattice

In this section, the procedure by which the horseshoe vortex lattice is laid out is described. The planform is divided chordwise and spanwise along the surface into trapezoidally shaped elemental panels; one horseshoe vortex is assigned to represent each panel. The horseshoe vortices are similar to those described in references 11 and 16 and are sketched in figure 2 for a typical panel. The horseshoe vortex is composed of three vortex lines: a bound vortex which is swept to coincide with the elemental-panel quarter-chord sweep angle in the plane of the wing and two trailing vortices which extend chordwise parallel to the free stream to infinity behind the wing. Figure 1 shows a typical chordwise row of horseshoe vortices on an arbitrary planform. The nominal width of these horseshoe vortices is the total semispan in the plane of the wing divided by the variable VIC. (See appendix A.)

The procedure for laying out the horseshoe vortices and the elemental panels is to begin at the left tip with the first chordwise row of vortices and then proceed toward the wing root. The actual spanwise locations of the chordwise rows of horseshoe vortices are adjusted so that there is always a trailing vortex filament at points where there are intersections of lines with breakpoints of the planform. This adjustment may cause the horseshoe vortex width to be narrower or wider than the nominal width. When a horseshoe vortex has one trailing vortex filament which coincides with a breakpoint, the width of the horseshoe vortex may vary from 0.5 to 1.5 times the nominal width. When both trailing legs coincide with breakpoints, the width may vary from a maximum of 1.5 times the nominal width to a minimum width of $(b/2)/2000$, as described previously in Section 2. For wings with zero dihedral angles, good results can be expected for horseshoe vortices of these widths. However, for planforms having dihedral, the span loading results may be poor when narrow (less than 0.5 times the nominal width) horseshoe vortices exist. Hence, special care must be used in describing a planform with dihedral so that these narrow horseshoe vortices will not be used. The number of chordwise rows actually laid out is given by the variable SSW.

In the chordwise direction, the horseshoe vortices are distributed uniformly and the number of vortices is given by either the variable SCW or TBLSCW (I). The maximum number of horseshoe vortices in the chordwise direction is 20 and in the spanwise direction the maximum number is 50 on a semispan. However, the total number of horseshoe vortices (either the product of SCW and SSW or the sum of TBLSCW (I)) permitted by the program is 120 on a semispan. The exact number generated by the program depends on the values of VIC and SCW and on the details of the planform. As many as one additional

chordwise row of horseshoe vortices may be generated by the program at each breakpoint outboard of the root. Wings with dihedral must always have at least two horseshoe vortices chordwise; wings without dihedral may have only one. The most desirable spanwise-to-chordwise horseshoe-vortex ratio is examined in that portion of the paper entitled "Effect of Vortex-Lattice Arrangement on Computed Aerodynamic Characteristics."

The Prandtl-Glauert correction factor is applied to the $\bar{x}$-coordinates and the tangents of the sweep angle of the horseshoe vortices at this point to account for compressibility effects.

Parametric studies can be performed on optional features selected by repeating the group two input data. These parameters include Mach number, vortex-lattice arrangement, desired lift coefficient, distribution of twist and camber, and sweep angle for a variable-sweep planform. The optional features include the computation of the rotary derivatives C_{l_p} or C_{L_q} and C_{m_q}. This computation is accomplished by repeating the information required by group two of the input data for each additional case. Any number of additional cases may be used for a given initial wing planform set. A few limitations for variable-sweep planforms which should be noted are (1) the pivot cannot be canted from the vertical, (2) no provisions have been made for handling dihedral in the geometry calculations for the variable-sweep panel or at the intersection of this panel with the fixed portion of the wing, and (3) there should always be a fixed-sweep panel between the root chord and the outboard variable-sweep panel.

PART II – VORTEX-STRENGTH COMPUTATION

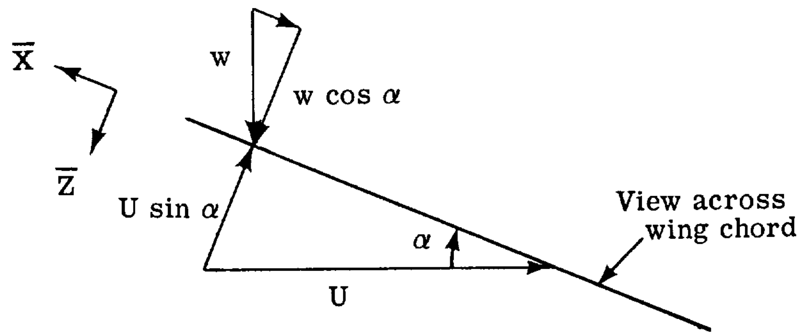
The vortex lattice laid out in Part I is now used in place of the real wing to generate the same flow field as the wing and to determine the forces and moments acting on the real wing. To perform these functions, the flow must be constrained so that it does not pass through the vortex lattice at specified points. These points are called control points and are at the midspan three-quarter-chord line of each elemental panel. This flow constraint is called the "no flow" condition and is equivalent to requiring that the flow be tangent to the real wing mean-camber surface. Simultaneous matching of the no flow condition at all the control points is used to compute the required vortex strengths. This can be conveniently expressed in matrix form as

$$\{C\} = [G]^{-1}\{B\} \tag{1}$$

where C_n, $G_{n,k}$, and B_k are the elements of these matrices.

The matrix $\{B\}$ represents the numerical values satisfying the boundary conditions which are presented in sketches (a) to (d) and equations (2) to (4). The traditional

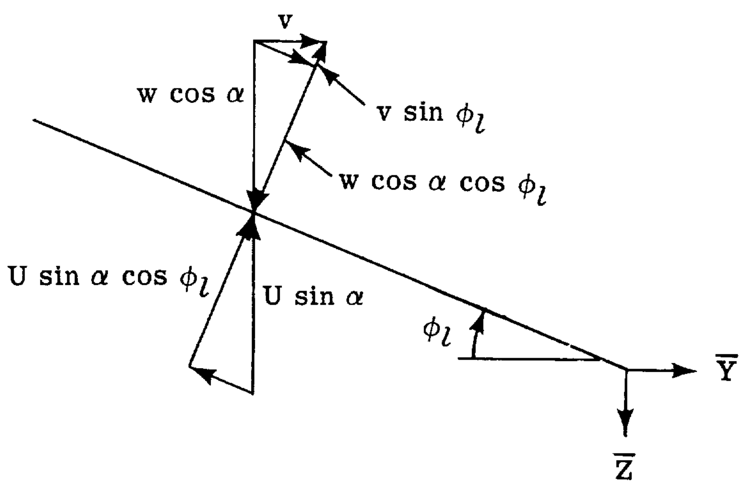
representation for flat wings is shown in sketch (a) of a wing chord.



Sketch (a)

$$w \cos \alpha - U \sin \alpha = 0 \tag{2}$$

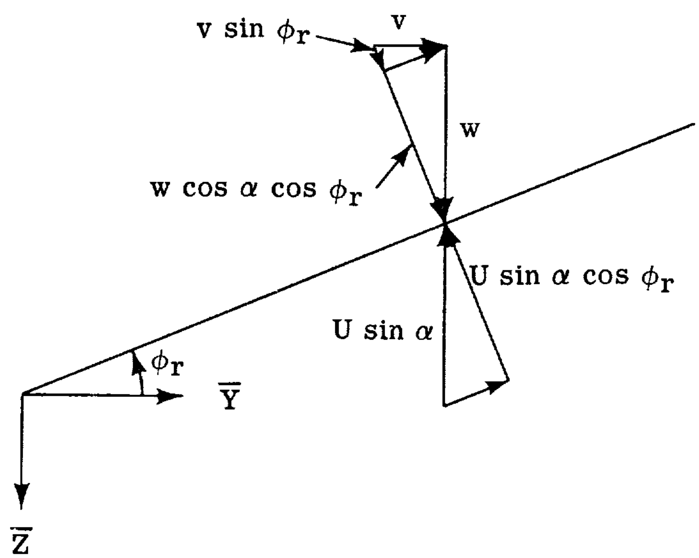
This boundary condition may be extended to represent wings with dihedral. This extension is shown in sketch (b), which is a view looking upstream toward the trailing edge of the left half of the wing span.



Sketch (b)

$$w \cos \alpha \cos \phi_l - v \sin \phi_l - U \sin \alpha \cos \phi_l = 0 \tag{3}$$

A view looking upstream toward the trailing edge of the right half of the wing span (sketch (c)) presents a somewhat different combination of velocity vectors for the no flow condition from that just considered.



Sketch (c)

$$w \cos \alpha \cos \phi_r + v \sin \phi_r - U \sin \alpha \cos \phi_r = 0 \tag{4}$$

In the geometry convention for this paper

$$\phi = \phi_l = -\phi_r$$

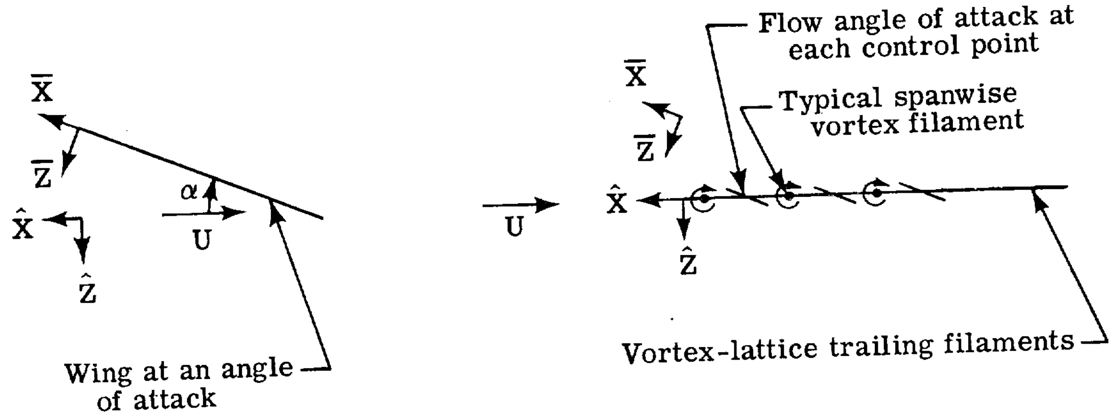
This relationship can be used to show that equations (2) and (3) are identical and have the form

$$w \cos \alpha \cos \phi - v \sin \phi - U \sin \alpha \cos \phi = 0 \tag{5}$$

or, for small angles of attack,

$$w - v \tan \phi \approx U\alpha \tag{6}$$

In the present formulation of a vortex lattice, the angle of attack in equation (5) refers to the flow at the control point for each elemental panel. The vortex lattice is located in a plane parallel to the free stream as shown in sketch (d).



Sketch (d)

The downwash velocity for a particular horseshoe vortex can be expressed as

$$w(x,y,z) = \frac{\Gamma}{4\pi} F_W(x',y,z,s,\psi',\phi) \tag{7}$$

where the downwash influence coefficient is

$$F_W(x',y,z,s,\psi',\phi) = \frac{(y \tan \psi' - x')\cos \phi}{(x')^2 + (y \sin \phi)^2 + \cos^2\phi(y^2\tan^2\psi + z^2\sec^2\psi' - 2yx' \tan \psi') - 2z \cos \phi \sin \phi(y + x' \tan \psi')}$$

$$\times \left\{ \frac{(x' + s \cos \phi \tan \psi')\cos \phi \tan \psi' + (y + s \cos \phi)\cos \phi + (z + s \sin \phi)\sin \phi}{\left[(x' + s \cos \phi \tan \psi')^2 + (y + s \cos \phi)^2 + (z + s \sin \phi)^2\right]^{1/2}} \right.$$

$$\left. - \frac{(x' - s \cos \phi \tan \psi')\cos \phi \tan \psi' + (y - s \cos \phi)\cos \phi + (z - s \sin \phi)\sin \phi}{\left[(x' - s \cos \phi \tan \psi')^2 + (y - s \cos \phi)^2 + (z - s \sin \phi)^2\right]^{1/2}} \right\}$$

$$- \frac{y - s \cos \phi}{(y - s \cos \phi)^2 + (z - s \sin \phi)^2} \left\{ 1 - \frac{x' - s \cos \phi \tan \psi'}{\left[(x' - s \cos \phi \tan \psi')^2 + (y - s \cos \phi)^2 + (z - s \sin \phi)^2\right]^{1/2}} \right\}$$

$$+ \frac{y + s \cos \phi}{(y + s \cos \phi)^2 + (z + s \sin \phi)^2} \left\{ 1 - \frac{x' + s \cos \phi \tan \psi'}{\left[(x' + s \cos \phi \tan \psi')^2 + (y + s \cos \phi)^2 + (z + s \sin \phi)^2\right]^{1/2}} \right\} \tag{8}$$

and the sidewash velocity can be expressed as

$$v(x,y,z) = \frac{\Gamma}{4\pi} F_V(x',y,z,s,\psi',\phi) \tag{9}$$

where the sidewash influence coefficient is

$$F_V(x',y,z,s,\psi',\phi) = \frac{x' \sin\phi - z\cos\phi\tan\psi'}{(x')^2 + (y\sin\phi)^2 + \cos^2\phi(y^2\tan^2\psi' + z^2\sec^2\psi - 2yx'\tan\psi') - 2z\cos\phi\sin\phi(y + x'\tan\psi')}$$

$$\times \left\{\frac{(x' + s\cos\phi\tan\psi')\cos\phi\tan\psi' + (y + s\cos\phi)\cos\phi + (z + s\sin\phi)\sin\phi}{\left[(x' + s\cos\phi\tan\psi')^2 + (y + s\cos\phi)^2 + (z + s\sin\phi)^2\right]^{1/2}}\right.$$

$$\left. - \frac{(x' - s\cos\phi\tan\psi')\cos\phi\tan\psi' + (y - s\cos\phi)\cos\phi + (z - s\sin\phi)\sin\phi}{\left[(x' - s\cos\phi\tan\psi')^2 + (y - s\cos\phi)^2 + (z - s\sin\phi)^2\right]^{1/2}}\right\}$$

$$+ \frac{z - s\sin\phi}{(y - s\cos\phi)^2 + (z - s\sin\phi)^2}\left\{1 - \frac{x' - s\cos\phi\tan\psi'}{\left[(x' - s\cos\phi\tan\psi')^2 + (y - s\cos\phi)^2 + (z - s\sin\phi)^2\right]^{1/2}}\right\}$$

$$- \frac{z + s\sin\phi}{(y + s\cos\phi)^2 + (z + s\sin\phi)^2}\left\{1 - \frac{x' + s\cos\phi\tan\psi'}{\left[(x' + s\cos\phi\tan\psi')^2 + (y + s\cos\phi)^2 + (z + s\sin\phi)^2\right]^{1/2}}\right\} \tag{10}$$

Then, by using equations (7) and (9) equation (6) can be rewritten as

$$\frac{\Gamma}{4\pi}\left(F_W - F_V\tan\phi\right) = U\alpha \tag{11}$$

For a vortex lattice of N elements, equation (11) can be expressed for a particular control point by

$$\sum_{n=1}^{N}\left(F_{W,n} - F_{V,n}\tan\phi_n\right)\frac{\Gamma_n}{U} = 4\pi\alpha \tag{12}$$

For symmetrical aerodynamic loading on each half of the wing, equation (12) may be expressed as

$$\sum_{n=1}^{N/2}\left(\overline{F}_{W,n} - \overline{F}_{V,n}\tan\phi_n\right)\frac{\Gamma_n}{U} = 4\pi\alpha \tag{13}$$

where

$$\overline{F}_{W,n} = F_{W,n}(x',y,z,s,\psi',\phi)_{\substack{\text{left}\\\text{panel}}} + F_{W,N+1-n}(x',y,z,s,\psi',\phi)_{\substack{\text{right}\\\text{panel}}} \tag{14}$$

and

$$\overline{F}_{V,n} = F_{V,n}(x',y,z,s,\psi',\phi)_{\substack{\text{left}\\\text{panel}}} + F_{V,N+1-n}(x',y,z,s,\psi',\phi)_{\substack{\text{right}\\\text{panel}}} \tag{15}$$

Figure 1 shows the locations of elemental panels n and (N + 1 - n). The matrix which is solved by the program is then

$$\left[\bar{F}_{w,n,k} - \bar{F}_{v,n,k} \tan \phi_n\right]\left\{\frac{\Gamma_n}{U}\right\} = 4\pi \left\{\alpha_k\right\} \tag{16}$$

where α_k describes the local angle of attack in radians at the control point. For the first solution, α_k is that angle of attack due to twist and camber when the root-chord angle of attack is zero; for the second solution, the angle of attack α_k is 1 rad for all the control points.

As previously mentioned, this program can be used to compute the rotary stability derivatives C_{l_p}, C_{m_q}, and C_{L_q}. This computation is accomplished by following the method outlined in reference 17 where the values of the boundary conditions of the second solution are changed to an equivalent quasi-steady-state rolling or pitching motion. For steady-state rolling at zero angle of attack, the boundary conditions lead to a linear twist whose angle variation across the span is

$$\alpha_k(2) = \frac{-p\hat{y}}{U} \tag{17}$$

For this computation, if the tip angle pb/2U is specified to be 5°, then equation (17) can be written as

$$\alpha_k(2) = \frac{-pb}{2U}\left(\frac{\hat{y}}{b/2}\right) = \frac{-5\pi}{180}\left(\frac{\hat{y}}{b/2}\right) \tag{18}$$

For pitching motion, the $\hat{Y}$-axis is the center of rotation. It is recommended that the perimeter points be specified so that the $\hat{Y}$-axis coincides with either the center of gravity or the wing quarter-chord. For steady pitching motion, the boundary conditions lead to a parabolic camber as can be seen from

$$\alpha_k(2) = \frac{-q\hat{x}}{U} = \frac{-\partial\hat{z}}{\partial\hat{x}} \tag{19}$$

Specifying that

$$\frac{q}{U} = \frac{5\pi}{180} \tag{20}$$

leads to

$$\alpha_k(2) = \frac{-5\pi\hat{x}}{180} \tag{21}$$

If any of the rotary derivatives are to be computed, the program assigns zero values for the $\alpha_k(1)$ terms and the appropriate boundary condition values for the $\alpha_k(2)$ terms.

In addition to solving for the circulation, solutions for section induced drag and leading-edge thrust are made at this point in the program by using a near-field approach. A detailed description of this implementation is given in Part III, Section 3.

PART III – AERODYNAMIC COMPUTATION

The circulation terms Γ_n/U computed in Part II are used in this part of the program to compute the lift and pitching-moment data for planforms with dihedral. A simplified procedure is used for zero-dihedral planforms. Then, the final form of the output data is obtained and printed for both planforms.

The procedure described in Section 1 is used for planforms with dihedral and for wing-tail planforms where the planforms are not at the same elevation. A special treatment is needed for both types of planforms because there are local sidewash and backwash velocities in addition to the free-stream velocity. The interaction of these velocity components with the spanwise bound vortex provides an additional lift force and the interaction of the sidewash with the chordwise bound vortex (that portion of the horseshoe vortex trailing leg ahead of the wing trailing edge) results in another and new lift force. Because of the computation procedure used in Section 1, these types of planforms must have a continuous variation in local chord from the wing tip to the wing root. As a result, streamwise perimeter edges can only be used at the wing tip or tip of the tail for these planforms.

Section 1. Lift and Moment Using Entire Horseshoe Vortex

The lift, pitching-moment, and rolling-moment output data for planforms which have a nonzero dihedral angle over any portion of the planform or for two planforms at different elevations are computed here by using the local sidewash and backwash velocities in addition to the free-stream velocity.

The procedure described herein for computing lift and pitching-moment data is performed twice: first, for the circulation terms due to twist and camber and, second, for the circulation terms due to an angle of attack of 1 rad. The lift, pitching-moment, and spanwise center-of-pressure data are computed for all elemental panels in a particular chordwise row; the procedure is then repeated for each chordwise row until the entire left half of the wing has been taken into account. For each elemental panel, the lift developed along the left chordwise bound vortex is computed first and then the lift along the spanwise bound vortex is computed. The Kutta-Joukowski theorem for lift per unit length of a vortex filament is used to compute lift for wings with dihedral and is given by the

following equation:

$$\tilde{l} = \rho V \Gamma \tag{22}$$

The circulation and velocity values used in equation (22) by this computer program are described in the discussion that follows.

The lift developed along the chordwise bound vortices in a chordwise row of horseshoe vortices varies from leading edge to trailing edge of the wing because of the longitudinal variation of both the sidewash velocity and the local value of vortex strength. In figure 3, it can be seen that there is no circulation along the chordwise bound vortex from the leading edge of the wing to the quarter-chord of the first elemental panel. As a result, no lift can be generated here. On the chordwise bound vortex from the quarter-chord of the first elemental panel to the quarter-chord of the second elemental panel, there is a constant value of circulation and a varying value of sidewash velocity. A special case occurs for the first elemental panel at the left wing tip; there the value of circulation just equals that of the first elemental panel of the first chordwise row of horseshoe vortices. Inboard from the tip, this chordwise bound vortex lies between two chordwise rows of horseshoe vortices, and its circulation is equal to the difference between the circulations of the first elemental panel of each row. The sidewash velocity used is the one computed at the three-quarter-chord on the left chordwise bound vortex of the first elemental panel.

The next lift to be computed is that developed along the chordwise bound vortex between the quarter-chord of the second elemental panel and the quarter-chord of the third elemental panel. This lift is computed in a manner similar to that of the first horseshoe vortex but there are differences and these are now explained. At the left wing tip, the sum of the circulation values of the first two elemental panels is used. Inboard from the tip between two chordwise rows of horseshoe vortices, the circulation is equal to the sum of the difference between the circulations of the first elemental panel of each row and the difference between the circulations of the second elemental panel of each row. The sidewash velocity used is the one computed at the three-quarter-chord on the left chordwise bound vortex of the second elemental panel.

This procedure continues through the last elemental panel in a chordwise row. However, the final chordwise bound vortex extends from the quarter-chord of the last elemental panel to the trailing edge of the wing so that its length is equal to only three-quarters of the length of the other chordwise bound vortices in the same chordwise row of horseshoe vortices. The sidewash velocity described in the foregoing procedure is given by the following equation:

$$\frac{v}{U} = \frac{1}{4\pi} \sum_{n=1}^{N/2} \frac{\Gamma_n}{U} \overline{F}_{v,n} \tag{23}$$

Horseshoe vortex filaments or their extensions which go through the point at which the velocity is being computed are eliminated in the computer program from equation (23) since a line vortex filament cannot induce a velocity on itself. The lift generated along an elemental length of chordwise bound vortex divided by free-stream dynamic pressure and reference wing area is given by

$$\frac{\hat{l}_t}{qS_{ref}} = \frac{2}{S_{ref}} \frac{\Delta\Gamma}{U} c_c \frac{v}{U} \tag{24}$$

where $\Delta\Gamma$ is the local value of circulation as described in the preceding paragraph and c_c is the chord or elemental length of the chordwise bound vortex. No lift is computed along the chordwise bound vortex at the root because the sidewash velocity is zero for symmetric loading and geometry.

The lift along the spanwise bound vortex depends on the values of free-stream, backwash, and sidewash velocities and on the circulation at the elemental panel. The sidewash velocity is given by equation (23) and the backwash velocity is computed from

$$\frac{u}{U} = \frac{1}{4\pi} \sum_{n=1}^{N/2} \frac{\Gamma_n}{U} \overline{F}_{u,n} \tag{25}$$

where

$$\overline{F}_{u,n} = F_{u,n}(x',y,z,s,\psi',\phi)_{\substack{\text{left}\\ \text{panel}}} + F_{u,N+1-n}(x',y,z,s,\psi',\phi)_{\substack{\text{right}\\ \text{panel}}} \tag{26}$$

and the backwash influence coefficient is

$$F_u(x',y,z,s,\psi',\phi) = \frac{z \cos\phi - y \sin\phi}{(x')^2 + (y \sin\phi)^2 + \cos^2\phi(y^2\tan^2\psi + z^2\sec^2\psi - 2yx' \tan\psi') - 2z \cos\phi \sin\phi(y + x' \tan\psi')}$$

$$\times \left\{ \frac{(x' + s \cos\phi \tan\psi')\cos\phi \tan\psi' + (y + s \cos\phi)\cos\phi + (z + s \sin\phi)\sin\phi}{\left[(x' + s \cos\phi \tan\psi')^2 + (y + s \cos\phi)^2 + (z + s \sin\phi)^2\right]^{1/2}} \right.$$

$$\left. - \frac{(x' - s \cos\phi \tan\psi')\cos\phi \tan\psi' + (y - s \cos\phi)\cos\phi + (z - s \sin\phi)\sin\phi}{\left[(x' - s \cos\phi \tan\psi')^2 + (y - s \cos\phi)^2 + (z - s \sin\phi)^2\right]^{1/2}} \right\} \tag{27}$$

Equations (8), (10), and (27) represent an extension of the original formulation by Glauert (ref. 16) for rectangular horseshoe vortices, the later formulation by Campbell (ref. 11) for a spanwise vorticity filament with sweep, and the recent formulation by Blackwell (ref. 12) for a rectangular horseshoe vortex with dihedral. In contrast, the present equations represent a subset of the formulation by Rubbert (ref. 3) in that the trailing legs are constrained to the free-stream direction.

A spanwise bound vortex filament is shown in figure 4 and the lift generated along this vortex filament comes from both the total axial velocity interacting with the component of the vortex filament parallel to the $\hat{Y}$-axis ($2s \cos \phi$) and the sidewash interacting with the component of the vortex filament parallel to the $\hat{X}$-axis ($2s \tan \psi \cos \phi$). The expression for this lift divided by free-stream dynamic pressure and reference area is

$$\frac{\hat{l}_s}{q_\infty S_{ref}} = \frac{2}{S_{ref}} \frac{\Gamma}{U}(2s)\left[\left(1 - \frac{u}{U}\right) + \frac{v}{U} \tan \psi\right]\cos \phi \tag{28}$$

The contribution of the lift of the elemental panel to pitching moment is given by

$$\frac{m_Y}{q_\infty S_{ref} c_{ref}} = \frac{\hat{l}_s}{q_\infty S_{ref}} \frac{\hat{x}_s}{c_{ref}} + \frac{\hat{l}_t}{q_\infty S_{ref}} \frac{\hat{x}_t}{c_{ref}} \tag{29}$$

To get the total wing lift and pitching-moment coefficients, these terms are summed over all the elemental panels which represent the wing in the following manner:

$$C_L = \frac{L}{q_\infty S_{ref}} = 2 \sum_{n=1}^{N/2} \left(\frac{\hat{l}_s}{q_\infty S_{ref}}\right)_n + \left(\frac{\hat{l}_t}{q_\infty S_{ref}}\right)_n \tag{30}$$

$$C_m = \frac{M_Y}{q_\infty S_{ref} c_{ref}} = 2 \sum_{n=1}^{N/2} \left(\frac{m_Y}{q_\infty S_{ref} c_{ref}}\right)_n \tag{31}$$

There are two values for each of these quantities; one for the surface loading due to twist and camber and the other for the surface loading at 1 rad angle of attack. From these quantities, four output terms are obtained. The lift-curve slope per radian is the value given by equation (30) (i.e., the lift coefficient at 1 rad angle of attack). The lift-curve slope per degree is

$$C_{L_\alpha} = \left(\frac{L}{q_\infty S_{ref}}\right)_a \Big/ 57.29578 \tag{32}$$

The longitudinal stability parameter about the origin of the X-axis for the wing is given by

$$\frac{\partial C_m}{\partial C_L} = \frac{\left(\dfrac{M_Y}{q_\infty S_{ref} c_{ref}}\right)_a}{\left(\dfrac{L}{q_\infty S_{ref}}\right)_a} \tag{33}$$

The pitching moment at zero lift is

$$C_{m_o} = \left(\frac{M_Y}{q_\infty S_{ref} c_{ref}}\right)_{tc} - \frac{\partial C_m}{\partial C_L}\left(\frac{L}{q_\infty S_{ref}}\right)_{tc} \tag{34}$$

The center of pressure in a spanwise direction is computed from the following expression:

$$y_{cp} = \frac{\sum_{n=1}^{N/2}\left[\left(\dfrac{\hat{l}_s}{q_\infty S_{ref}}\right)_{a,n} \hat{y}_{s,n} + \left(\dfrac{\hat{l}_t}{q_\infty S_{ref}}\right)_{a,n} \hat{y}_{t,n}\right]}{\dfrac{1}{2}\left(\dfrac{L}{q_\infty S_{ref}}\right)_a \left(\dfrac{b}{2}\right)} \tag{35}$$

The span-load coefficients are obtained from the lift along the spanwise and chordwise bound vortices of each horseshoe vortex. Before converting the lift expressions to span-load coefficients, a few basic definitions should be emphasized. The lift in equations (24) and (28) is lift in units of force developed over a span equal to the width of a horseshoe vortex. Therefore, lift per unit length of span is

$$l = \frac{\hat{l}}{2s \cos \phi} \tag{36}$$

The span-load coefficient for an elemental panel is developed as follows:

$$\frac{c_l c}{C_L c_{av}} = \frac{\left(\dfrac{l}{q_\infty c}\right)c}{C_L c_{av}} = \left(\frac{\hat{l}}{q_\infty S_{ref}}\right)\frac{S_{ref}}{C_L 2s_n \cos \phi c_{av}} \tag{37}$$

where

$$c_{av} = \frac{S_T}{b} \tag{38}$$

and

$$T = \frac{S_{ref}}{2s_n \cos \phi c_{av}} \tag{39}$$

so that

$$\frac{c_l c}{C_L c_{av}} = \frac{\hat{l}}{q_\infty S_{ref}} \frac{T}{C_L} \tag{40}$$

At a particular spanwise location, each of these lifts are summed chordwise and converted to span-load coefficients by the following equations: For lift along the spanwise bound vortex filament,

$$\left(\frac{c_l c}{C_L c_{av}}\right)_s = T \sum_{i=1}^{j} \left(\frac{\hat{l}_s}{q_\infty S_{ref}}\right)_i \frac{1}{C_L} \tag{41}$$

For lift along the chordwise bound vortex filament,

$$\left(\frac{c_l c}{C_L c_{av}}\right)_t = T \sum_{i=1}^{j} \left(\frac{\hat{l}_t}{q_\infty S_{ref}}\right)_i \frac{1}{C_L} \tag{42}$$

Figure 5 shows the spanwise distribution of the span-load coefficients obtained from equations (41) and (42) for a wing with dihedral. The results of these equations must now be combined to get the final distribution. It is assumed that the span-load coefficient should be zero at the wing tip, a result which cannot be obtained by direct combination of the results of equations (41) and (42). Since the vortex-lattice procedure is a finite approximation for the continuous variation of circulation across the wing span, each value of circulation represents the average value over the width of one horseshoe vortex. For this calculation, it is assumed that the circulation terms or span-load terms are correct only at the center of each row of horseshoe vortices. The lift along the spanwise bound vortices is computed here and is used directly; whereas, the lift along the chordwise bound vortices is interpolated linearly to determine its value at the midpoint of each row. These two values of lift are then combined as illustrated in figure 5 to give the final spanwise distribution of span-load coefficients.

In order to determine the damping-in-roll parameter of wings with dihedral, the lift distribution which results from the antisymmetrical span loading must be combined with the appropriate spanwise moment arm. This combination can be expressed as

$$C_l = \frac{2}{q_\infty S_{ref} b}\left[\sum_{n=1}^{N/2}\left(\hat{l}_t \hat{y}_t\right)_n + \sum_{n=1}^{N/2}\left(\hat{l}_s \hat{y}_s\right)_n\right] \tag{43}$$

and, thus,

$$C_{l_p} = \frac{\partial C_l}{\partial\left(\frac{pb}{2U}\right)} \approx \frac{C_l}{5\pi/180} \tag{44}$$

Section 2. Lift and Pitching and Rolling Moments Using Only Spanwise Filament of Horseshoe Vortex

The computation of the lift, pitching-moment, and rolling-moment output data for wings which have no dihedral over any portion of the wing is described in this section. All the lift is generated by the free-stream velocity crossing the spanwise vortex filament since there will be no sidewash or backwash velocities. For a single elemental panel, the lift per unit length of vorticity is

$$\tilde{l} = \rho U \Gamma \cos\psi \tag{45}$$

Since the length of vorticity is $2s/\cos\psi$, the resultant lift is given by

$$\hat{l} = \tilde{l}\,\frac{2s}{\cos\psi} \tag{46}$$

Then, the lift per unit of span is defined by

$$l = \frac{\hat{l}}{2s} = \rho U \Gamma \tag{47}$$

and is nondimensionalized in the following form for later use as

$$\frac{l}{q_\infty c_{av}} = \frac{2}{c_{av}}\frac{\Gamma}{U} \tag{48}$$

For a chordwise row

$$\frac{c_l c}{c_{av}} = \sum_{i=1}^{j}\left(\frac{l}{q_\infty c_{av}}\right)_i \tag{49}$$

The total lift coefficient is obtained by integrating the lift over the span as given by

$$C_L = \frac{S_T}{S_{ref}} \int_0^1 \frac{c_l c}{c_{av}} \, d\left(\frac{\hat{y}}{b/2}\right) \tag{50}$$

or approximately by

$$C_L = \frac{8}{S_{ref}} \sum_{n=1}^{N/2} \frac{\Gamma_n}{U} s_n \tag{51}$$

The lift-curve slope per radian is obtained from a lift coefficient based on the circulation terms obtained at 1 rad angle of attack.

The longitudinal stability about $\hat{Y}$-axis is given by

$$\frac{\partial C_m}{\partial C_L} = \frac{1}{c_{ref}} \frac{\sum_{n=1}^{N/2} \frac{\Gamma_{a,n}}{U} \hat{x}_{s,n} s_n}{\sum_{n=1}^{N/2} \frac{\Gamma_{a,n}}{U} s_n} \tag{52}$$

The pitching moment at zero lift is

$$C_{m_O} = \frac{8}{c_{ref} S_{ref}} \sum_{n=1}^{N/2} \frac{\Gamma_{tc,n}}{U} \hat{x}_{s,n} s_n - \frac{\partial C_m}{\partial C_L} C_{L,tc} \tag{53}$$

The center of pressure in a spanwise direction is

$$\hat{y}_{cp} = \frac{1}{b/2} \frac{\sum_{n=1}^{N/2} \frac{\Gamma_{a,n}}{U} \hat{y}_{s,n} s_n}{\sum_{n=1}^{N/2} \frac{\Gamma_{a,n}}{U} s_n} \tag{54}$$

The span-load coefficient is

$$\frac{c_l c}{C_L c_{av}} = \frac{\frac{b}{2} \sum_{i=1}^{j} \frac{\Gamma_i}{U}}{2 \sum_{n=1}^{N/2} \frac{\Gamma_n}{U} s_n} \tag{55}$$

The same procedure used to compute the damping-in-roll parameter for wings with dihedral can be used to compute C_{l_p} for zero-dihedral wing planforms except that the contribution of the chordwise bound vortex is eliminated. Thus, equation (43) becomes

$$C_l = \frac{2}{q_\infty S_{ref} b} \left[\sum_{n=1}^{N/2} 2\left(\frac{\Gamma}{U}\right)_n \hat{y}_{s,n} 2 s_n \right] \tag{56}$$

and likewise

$$C_{l_p} \approx \frac{C_l}{5\pi/180} \tag{57}$$

Section 3. Output Data Preparation

This section of the program is used to compute the last portion of the data listed in the final output. These data include the damping-in-pitch parameter, the lift coefficient due to pitch rate, the induced drag parameter, the angle of attack for zero lift, the angle of attack for the desired lift coefficient, the basic span load distribution, and the additional span load distribution.

The pitch derivatives can be computed by using the vortex strengths obtained with the boundary condition values which represent a constant pitching motion. These vortex strengths are employed to compute C_L and C_m which, in turn, are used as follows:

$$C_{m_q} = \frac{\partial C_m}{\partial\left(\frac{qc}{2U}\right)} \approx \frac{C_m}{\frac{5\pi}{180} \frac{c_{ref}}{2}} \tag{58}$$

and

$$C_{L_q} = \frac{\partial C_L}{\partial\left(\frac{qc}{2U}\right)} \approx \frac{C_L}{\frac{5\pi}{180} \frac{c_{ref}}{2}} \tag{59}$$

In this paper, induced drag parameters are computed by both far-field and near-field methods. The far-field method is based on the lifting-line concepts employed in the Treffetz plane by Munk and the induced drag parameter thereby obtained can be expressed mathematically as

$$\frac{C_{D,i}}{C_L^2} = \frac{b^2}{C_L^2 S_{ref}} \int_{-1}^{1} \gamma \alpha_i \, d\eta \tag{60}$$

This equation has been reformulated by Multhopp using, in part, his quadrature formula and is programed here in the form presented by equation (146) in reference 18. Equation (60) can give good results for wings without dihedral but should be used only as a guide for wings with dihedral, since no vertical displacement of the span loadings is taken into account. For wings having dihedral, a method such as that developed in reference 19 or the near-field method should be used to compute the induced drag. Even for wings without dihedral, good results can only be expected for the far-field method when a large number of chordwise rows of horseshoe vortices are specified since the interpolating procedure chosen to represent the variation of γ with $\sin^{-1}\eta$ was a linear curve fit between consecutive pairs of data points. This curve fit requires that a sufficient number of data points be available near the wing tip where the gradient of the γ - $\sin^{-1}\eta$ curve is the greatest.

The near-field computation for the induced drag is based on combining for each elemental panel the lift and leading-edge thrust as follows:

$$\frac{d_{ii}}{q_\infty} = \alpha \frac{l}{q_\infty} - \frac{t}{q_\infty} \tag{61}$$

where the lift per unit of span l/q_∞ is computed by equation (48) for planforms without dihedral and by equations (24) and (28) for planforms with dihedral. The leading-edge thrust per unit of span is computed by using the Kutta-Joukowski theorem where the induced and free-stream velocity components parallel to the $\bar{Y}$-$\bar{Z}$ plane interact with the spanwise bound vortex filament as follows:

$$\frac{t}{q_\infty} = -2\left(\frac{w}{U} - \frac{v}{U}\tan\phi - \alpha\right)\left(\frac{\Gamma}{U}\right)_{a,rad} \tag{62}$$

There is no contribution of the chordwise bound vortex filaments to the leading-edge thrust. In contrast, however, there is a contribution of the lift due to the chordwise bound vortex filament included in the induced drag term. (See eqs. (6) and (24).) It should be noted that this equation is evaluated at an angle of attack of 1 rad and that the circulation used is the one due to the additional loading only.

These results are then summed along each chordwise row to get the following section leading-edge thrust:

$$\frac{c_t c}{2b} = \frac{1}{2b} \sum_{i=1}^{j} \left(\frac{t}{q_\infty}\right)_i \tag{63}$$

From equation (63) the section suction coefficient is computed as

$$\frac{c_s c}{2b} = \left(\frac{c_t c}{2b}\right) \Big/ \cos \Lambda \tag{64}$$

Then, the section induced drag for a chordwise row of horseshoe vortices is

$$\frac{c_{d,ii} c}{2b} = \alpha \left(\frac{c_l c}{C_L c_{av}}\right) \frac{c_{av} S_{ref} \left(C_{L_\alpha}\right)_{rad}}{2bS_T} - \frac{c_t c}{2b} \tag{65}$$

Finally, the near-field solution for the induced drag parameter is

$$\frac{C_{D,ii}}{C_L^{\,2}} = \frac{4b}{S_{ref} \left(C_{L_\alpha}\right)_{rad}^{2}} \sum_{k=1}^{\overline{N}_s} \left(\frac{c_{d,ii} c}{2b}\right)_k 2s_k \cos \phi_k \tag{66}$$

In addition, the leading-edge thrust and suction coefficients are computed similarly as

$$C_T = \frac{2}{S_{ref}} \sum_{k=1}^{\overline{N}_s} \left(\frac{c_t c}{2b}\right)_k 2s_k \cos \phi_k \tag{67}$$

and

$$C_S = \frac{2}{S_{ref}} \sum_{k=1}^{\overline{N}_s} \left(\frac{c_s c}{2b}\right)_k 2s_k \cos \phi_k \tag{68}$$

The angle of attack for zero lift is computed by

$$\alpha_o = -\frac{C_{L,tc}}{C_{L_\alpha}} \tag{69}$$

The angle of attack required for the additional loading and basic loading combined to produce the input value of the desired lift coefficient is

$$\alpha_d = \frac{C_{L,d}}{C_{L_\alpha}} + \alpha_o \tag{70}$$

The basic load due to twist and/or camber is the load on the wing when the lift coefficient is zero. This load is obtained from the values of $c_l c/c_{av}$ for each elemental panel as follows:

$$\left(\frac{l}{q_\infty c_{av}}\right)_b = \left(\frac{l}{q_\infty c_{av}}\right)_{tc} - \left(\frac{l}{q_\infty c_{av}}\right)_a \frac{C_{L,tc}}{C_{L,a}} \tag{71}$$

Equation (71) is then summed for each chordwise row for the span load distribution of basic load to give

$$\left(\frac{c_l c}{c_{av}}\right)_B = \sum_{i=1}^{j}\left(\frac{l}{q_\infty c_{av}}\right)_{i,b} \tag{72}$$

The span load distribution at the input value of desired lift coefficient is

$$\left(\frac{c_l c}{c_{av}}\right)_d = \left(\frac{c_l c}{c_{av}}\right)_B + \sum_{i=1}^{j}\left(\frac{l}{q_\infty c_{av}}\right)_{i,a} \frac{C_{L,d}}{C_{L,a}} \tag{73}$$

In addition, the span load distribution $c_l c/C_{L,\tau} c_{av}$ and local lift-coefficient ratio $c_l/C_{L,\tau}$ are listed where the lift coefficients are based on the lift due only to additional loading and the total lift coefficient $C_{L,\tau}$ is based on the true planform area S_τ. Also listed is the distribution of local chord ratio c/c_{av}.

The incremental pressure coefficient is defined as

$$\Delta C_{p,n} = \frac{\left(p_{lower} - p_{upper}\right)_n}{q_\infty} \tag{74}$$

Since the pressure is assumed to be uniform over an elemental panel,

$$\Delta C_{p,n} = \frac{(l/c)_n}{q_\infty} \tag{75}$$

which is used in the program. For planforms without dihedral, equation (75) can be expressed as

$$\Delta C_{p,n} = \frac{\rho U \Gamma_n / c_n}{q_\infty} = \frac{2}{c_n} \frac{\Gamma_n}{U} \tag{76}$$

EFFECT OF VORTEX-LATTICE ARRANGEMENT ON COMPUTED AERODYNAMIC CHARACTERISTICS

Several sets of lifting-surface planforms have been investigated to determine the effect of the vortex-lattice arrangement on the computed aerodynamic characteristics. The first four sets of planforms had two prescribed leading-edge sweep angles in combination with three different taper ratios for aspect ratios of 2, 4.5, and 7. Calculated results for these planforms show that for different vortex-lattice arrangements, smaller variations of y_{cp} and $C_{D,i}/C_L^2$ are produced than of C_{L_α}, $\partial C_m/\partial C_L$, and $C_{D,ii}/C_L^2$. The variation of y_{cp} with vortex-lattice arrangement is presented for unswept wings of taper ratio 1.0 in figure 6. These data indicate that increasing $\overline{N}_s$ leads toward converging results for y_{cp} for all $\overline{N}_c$.

The variations of C_{L_α}, $\partial C_m/\partial C_L$, $C_{D,i}/C_L^2$, and $C_{D,ii}/C_L^2$ with vortex-lattice arrangement are presented in figure 7 for unswept planforms with a taper ratio of 1.0 and in figures 8 to 10 for planforms with a leading-edge sweep angle of 45° and taper ratios of 1.0, 0.5, and 0, respectively. These data indicate the following conclusions. A spanwise increase in the number of chordwise rows of horseshoe vortices $\overline{N}_s$ leads to converging answers. For these simple planforms, the $\overline{N}_s$ required for convergence of C_{L_α} to a particular value is sufficient for convergence of $\partial C_m/\partial C_L$ and $C_{D,i}/C_L^2$ and should be 20 or larger. Also, the computed values of C_{L_α}, $\partial C_m/\partial C_L$, and $C_{D,ii}/C_L^2$ in most instances have a definite dependence upon $\overline{N}_c$. In particular, $\overline{N}_c$ controls the asymptotic levels that these aerodynamic characteristics attain with varying $\overline{N}_s$. These asymptotic levels approach a converged result when $\overline{N}_c$ is increased. Differences between asymptotic levels which occur for consecutive $\overline{N}_c$ values decrease with increasing $\overline{N}_c$ and the largest difference in asymptotic levels is obtained by increasing $\overline{N}_c$ from 1 to 2. Therefore, an $\overline{N}_c$ value of 2 should be the minimum used. Higher values of $\overline{N}_c$ have little effect on C_{L_α}; however, increasing $\overline{N}_c$ to 4 or more can provide additional improvement in $\partial C_m/\partial C_L$ and $C_{D,ii}/C_L^2$. In contrast, the calculated results indicate that $\overline{N}_c$ has little effect on $C_{D,i}/C_L^2$. The asymptotic levels of $C_{D,i}/C_L^2$ and $C_{D,ii}/C_L^2$ when $\overline{N}_s$ is greater than 20 can be compared with those of $1/\pi A$. This comparison shows that $C_{D,i}/C_L^2$ converges to a value greater than $1/\pi A$, as expected, whereas $C_{D,ii}/C_L^2$ converges in a less uniform manner to a value less than $1/\pi A$.

Since $C_{D,ii}/C_L{}^2$ is computed by using equations (65) and (66) which are based on c_t and c_l, these results indicate that c_t may be overpredicted. However, a comparison can be made in figure 11 between the distribution of section thrust computed for an $A = 4$ delta wing by the vortex-lattice and Wagner's (ref. 14) methods. It can be seen that the resulting magnitudes predicted by the two different methods compare closely in general shape and lead to comparable overall thrust results. From additional computer studies it has been found that the $\overline{N}_c = 10$ and $\overline{N}_s = 12$ pattern used for the results shown in figure 11 also provides reasonable results for other delta wings. The large number of chordwise stations is necessary on such wings so that the effect of the induced camber loading can be properly taken into account. Although the correct thrust coefficient can be obtained from the far-field induced drag and lift-curve slope directly, only by finding the appropriate combination of $\overline{N}_c$ and $\overline{N}_s$ will the induced-drag results be the same for both methods. This check provides a method by which the correct distribution of section thrust can be obtained. The results presented in figures 7 to 10 show how difficult it is to make this check even for some simple planforms.

To determine the effect of vortex-lattice arrangement on C_{l_p}, C_{m_q}, and C_{L_q}, additional computer studies were made with a cropped double-delta planform having an inboard leading-edge sweep angle of 83°, an outboard leading-edge sweep angle of 62°, and an aspect ratio of 1.49. Results of these studies showed two trends. For estimating C_{l_p}, a large value of $\overline{N}_s$ is desired with at least two horseshoe vortices ($\overline{N}_c$) in each row. For estimating C_{m_q} and C_{L_q}, a large value of $\overline{N}_c$ (8 or more) is desirable with a nominal value of $\overline{N}_s$ of 8 or 10.

A final set of computer studies were made with the wing-body-tail configuration illustrated in sample cases 2, 3, and 4. The aerodynamic characteristics were computed for this complex configuration by using 22 different vortex-lattice arrangements which had a total number of vortices on a semispan ranging from 17 to 120. Results showed very little variation of C_{L_α}, y_{cp}, and $C_{D,i}/C_L{}^2$ with changes in the vortex lattice. However, there is a very significant variation in $\partial C_m/\partial C_L$ (fig. 12). Two different types of vortex patterns were employed to produce these variations. The first type used uniform values of $\overline{N}_c$ at each row of horseshoe vortices on the wing-body and on the tail. These $\overline{N}_c$ values were used in combination with three values of $\overline{N}_s$. The results with uniform distribution of $\overline{N}_c$ reveal a large variation of $\partial C_m/\partial C_L$ with increasing $\overline{N}_c$. These results can be shown, by cross-plotting, to be similar to those in figure 7 because increasing $\overline{N}_s$ for a given value of $\overline{N}_c$ has little effect on $\partial C_m/\partial C_L$ but increasing $\overline{N}_c$ caused noticeable changes between asymptotic levels of $\partial C_m/\partial C_L$ for all values of $\overline{N}_s$ considered, especially at the smaller values of $\overline{N}_c$. The second type of vortex pattern used uniform values of $\overline{N}_c$ on the outboard wing panel and outboard

tail panel and then used an increased density of elemental panels on the inboard portion of the planform. The increased density is illustrated in the input data for sample case 2. The purpose of these additional inboard elemental panels was to make their chords more uniform. This type of vortex pattern virtually eliminated the variation of $\partial C_m/\partial C_L$ with $\overline{N}_c$. These computed results agree with unpublished experimental data for this configuration to within $0.01x/c_{ref}$ and indicate that good results can be obtained for complex planforms with large changes in chord by arranging the pattern of elemental panels so that the largest panel chords are no more than two to three times the smallest panel chords.

SAMPLE CASES

Sample cases have been prepared to illustrate most of the program options available. Sketches of the sample cases along with corresponding input data and output data listings are provided in appendix C. The sample cases are as follows:

Sample case	Configuration	Description	Page
1	70	Fixed sweep wing with dihedral and twist and camber	46
2	13	Wing-body-tail combination with variable $\overline{N}_c$	48
3	113	Wing-body-tail combination with variable $\overline{N}_c$ and tail incidence of -10^o	48
4	110	Wing-body-tail combination with variable sweep of wing outer panel	48
5	15	Cropped double-delta wing with variable $\overline{N}_c$ and twist and camber to illustrate drag polar option	50
6	215	Cropped double-delta wing to illustrate C_{l_p} computation	50
7	315	Cropped double-delta wing to illustrate C_{L_q} and C_{m_q} computation	50

CONCLUDING REMARKS

A FORTRAN computer program for estimating the aerodynamic characteristics of lifting surfaces in subsonic compressible flow has been described along with the input and output variables. Also, a detailed description of the program organization and programed equations has been given. The program has been used to compute the aerodynamic

characteristics for several configurations that were selected to show the range of planforms to which the program may be applied. In addition, results from parametric studies of the effects of vortex-lattice arrangement on some of the computed aerodynamic characteristics are presented. From these results, the following recommendations are provided as guidance in determining the number of spanwise rows of horseshoe vortices and the number of horseshoe vortices chordwise in each row to use to represent a simple wing planform or to represent a more complex planform such as a wing-body-tail combination:

1. For simple planforms, (a) use at least 20 spanwise rows and four horseshoe vortices chordwise for good values of C_{L_α}, $\partial C_M / \partial C_L$, y_{cp}, and $C_{D,i} / C_L^2$, and (b) use a vortex-lattice arrangement which gives similar answers for $C_{D,i}$ and $C_{D,ii}$ inasmuch as a desirable vortex-lattice arrangement for good values of $C_{D,ii}$, C_T, and C_S is difficult to determine because it is very dependent on the planform.

2. For a rolling planform, use a large number of spanwise rows and at least two horseshoe vortices chordwise.

3. For a pitching planform, use eight to 10 spanwise rows and eight or more horseshoe vortices chordwise.

4. For wing-body-tail combinations, use at least 10 to 15 spanwise rows and vary the number of horseshoe vortices chordwise so that the local panel chords differ by no more than a factor of 2 to 3 from the smallest to the largest.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., October 28, 1970.

APPENDIX A

INPUT DATA

GROUP ONE

The input data required for the reference planform is described in the order that it is called for by the computer program. All coordinates and slopes should be given for the left half of the wing planform. The axis system used is given in figure 1. The $\bar{y} = 0$ intercept coincides with the root chord and is positive pointing along the right wing. Although the $\bar{x} = 0$ intercept usually coincides with the intersection of the leading edge at the root chord, it may lie anywhere along the root chord; $\bar{X}$ is positive pointing into the wind. All the cards use a format of (8F10.6) for group one data.

Data for the first card are to be supplied in the following order:

PLAN — Number of planforms for the configuration; use 1 or 2

TOTAL — Number of sets of group two data specified for the configuration

CREF — Reference chord of the configuration
This chord is used only to nondimensionalize the pitching-moment terms and must be greater than zero.

SREF — Reference area of the configuration
This area is used only to nondimensionalize the computed output data such as lift and pitching moment and must be greater than zero.

The data required to define each planform are then provided by a set of cards. The initial card in this set is composed of the following data:

AAN (IT) — Number of line segments used to define left half of a wing planform (does not include plane of symmetry)
A maximum of 24 line segments may be used.

XS (IT) — x location of the pivot; use 0 on a fixed wing
The axis system used is given in figure 1.

YS (IT) — y location of the pivot; use 0 on a fixed wing

RTCDHT (IT) — Vertical distance of particular planform being read in with respect to the wing root chord height; use 0 for a wing

The rest of this set of data requires one card for each line segment used to define the basic planform (variable AAN (IT)). All data described below are required on all except the last card of this set; the last card uses only the first two variables in the following list:

XREG (I, IT) — x location of ith breakpoint
The first breakpoint is located at the intersection of the left wing leading edge with the root chord. They are numbered in increasing order for each intersection of lines in a counterclockwise direction.

YREG (I, IT) — y location of ith breakpoint

DIH (I, IT) — Dihedral angle (degrees) in $\overline{Y}$-$\overline{Z}$ plane of line from breakpoint i to i + 1; positive upward
Along a streamwise line, the dihedral angle is not defined; use 0 for these lines.

AMCD — The move code
This number indicates whether the line segment i is on the movable panel of a variable-sweep wing. Use 1 for a line which is fixed or 2 for a line which is movable.

GROUP TWO

Three sections of data may be used for group two data. The first section must always be included; it is a single card which describes the details of the particular configuration for which the loading is desired. This card requires a format of (8F5.1, F10.4, F5.1, F10.4). The second section is required when the number of horseshoe vortices used in each chordwise row is not the same; it consists of two or more cards. The third section is used when the wing has a twist and/or camber distribution and may consist of up to 15 cards, depending on the number of horseshoe vortices. The cards in the second and third sections use a format of (8F10.4).

Section one data are to be supplied in the following order:

CONFIG — An arbitrary configuration number which may include up to four digits

SCW — The number of chordwise horseshoe vortices to be used to represent the wing; a maximum value of 20 may be used
If set to 0, then a table of the number of chordwise horseshoe vortices from tip to root must be provided as TBLSCW (I). This SCW = 0 option can be used only on wings without dihedral and for coplanar wing-tail combinations.

VIC — The nominal number of spanwise rows at which chordwise horseshoe vortices will be located

The variable VIC must not cause more than 50 spanwise rows to be used by the program to describe the wing. In addition, the product of SSW and SCW cannot exceed 120. If SCW is 0, then the sum of the values in TBLSCW (I) cannot exceed 120. The use of the variable VIC is discussed in detail in Part I, Section 3 of the Program Description.

MACH — Mach number

Use a value other than 0 only if the Prandtl-Glauert compressibility correction factor $\beta = \sqrt{1 - M_\infty^2}$ is to be applied. It should be less than the critical Mach number.

CLDES — Desired lift coefficient

The number specified here is used to obtain the span load distribution at a particular lift coefficient. If this answer is not required, use 1 for this quantity. If a drag polar for C_L values from -0.1 to 1 is desired, use 11 for this quantity.

PTEST — C_{l_p} indicator

If the damping-in-roll parameter is desired, use 1 for this quantity. Except for the incremental pressure coefficients and C_{l_p}, all other aerodynamic data will be omitted. Use 0 if C_{l_p} is not desired.

QTEST — C_{L_q} and C_{m_q} indicator

If these stability derivatives are desired, use 1 for this quantity. Except for ΔC_p, C_{L_q}, and C_{m_q}, all other aerodynamic data will be omitted. It should be noted that both PTEST and QTEST cannot be set equal to 1 for a particular configuration. Use 0 if C_{L_q} and C_{m_q} are not desired.

TWIST (1) — Twist code for first planform

If this planform has no twist and/or camber, use a value of 0. When this planform has twist and/or camber, use a value of 1 for this code and provide data for section three.

SA (1) — Variable-sweep angle for the first planform

Specify leading-edge sweep angle (degrees) for the first movable line adjacent to the fixed portion of the planform. For a fixed planform, this quantity may be omitted.

TWIST (2) — Twist code for the second planform

SA (2) — Variable-sweep angle for the second planform

Section two data are required if SCW is 0. Data for the first variable go on the first card and data for the second variable go on the second and following cards. The data to be supplied are

STA — Total number of spanwise rows of horseshoe vortices per semispan
This variable sets the number of values of TBLSCW (I) to be read in.

TBLSCW (I) — Number of horseshoe vortices in each row starting at the row near the tip of the first planform and proceeding to the row near the root
If a second planform has been specified, the table of chordwise rows concludes with number of horseshoe vortices in each row of the second planform. For an example, see sample case 2.

Section three data are described as follows: If the configuration has no twist and/or camber, the local angles of attack are not specified since the program will set them equal to 0. If the configuration consists of two planforms, local angles of attack may be specified for both or only one of the two planforms. The twist code describes the input to the computer.

ALP (NV) — Local angles of attack in radians
These are the values at the control point for each horseshoe vortex on the wing when the root-chord angle of attack is 0°. These data will usually require several cards. For the first value on the first card, use the local angle of attack for the horseshoe vortex nearest the first planform leading edge at the tip; for the second value, use the angle of attack for the horseshoe vortex immediately behind in a chordwise direction. Continue with the rest of the chordwise row of horseshoe vortices at the tip; then continue inboard at the next chordwise row in the same manner to the root until local angles of attack for all the control points have been specified.

APPENDIX B

OUTPUT DATA

The printed results of this computer program appear in two sections: geometry data and aerodynamic data.

GEOMETRY DATA

The geometry data are described in the order that they are found on the printout. The first group of data describes the basic planform: It states the numbers of lines used to describe the planform, root chord height, and pivot position and then lists the breakpoints, sweep and dihedral angles, and move codes. These data are a listing of the input data except for the sweep angle which is computed from the input data.

The second group of data describes the particular planform for which the aerodynamic data are being computed. Included are the configuration number, the sweep position, a listing of the breakpoints of the wing planform ($\bar{x}$, $\bar{y}$, and $\bar{z}$), the sweep and dihedral angles, and the move codes. These data are listed primarily for variable-sweep wings to provide a definition of the planform where the outer panel sweep is different from that of the reference planform.

The third group of data presents a detailed description of the horseshoe vortices used to represent the planform. These data are listed in nine columns with each line describing one elemental panel of the wing in the same order that the twist and/or camber angles of attack are provided. (See ALP (NV) in appendix A.) The following items of data are presented for each elemental panel:

X C/4	x location of quarter-chord at horseshoe vortex midspan
X 3C/4	x location of three-quarter-chord at horseshoe vortex midspan This is the x location of the control point.
Y	y location of horseshoe vortex midspan
Z	z location of horseshoe vortex midspan
S	Semiwidth of horseshoe vortex
C/4 SWEEP ANGLE	Sweep angle of quarter-chord

DIHEDRAL ANGLE	Dihedral angle of elemental panel
LOCAL ALPHA IN RADIANS	Local angle of attack at control point (X 3C/4,Y,Z)
DELTA CP AT DESIRED CL =	ΔC_p for each elemental panel when wing lift is $C_{L,d}$

The fourth group of data presents the following geometric data:

REF. CHORD	Reference chord of wing
C AVERAGE	Average chord (true planform area divided by true span)
TRUE AREA	True area computed from planform listed in second group of geometry data
REF. AREA	Reference area
B/2	True semispan of planform listed in second group of geometry data
REF. AR	Reference aspect ratio computed from reference planform area and true span
TRUE AR	True aspect ratio computed from true planform area and true span
MACH NUMBER	Mach number

AERODYNAMIC DATA

The aerodynamic data are described in the order that they are found on the printout. Note that C_{L_α}, $C_{L,Twist}$, $\partial C_m/\partial C_L$, C_{m_o}, $C_{D,i}/C_L{}^2$, and $C_{L,d}$ are based on the specified reference dimensions.

DESIRED CL	Desired lift coefficient specified in input data for complete configuration
COMPUTED ALPHA	$C_{L,d}/C_{L_\alpha}$, angle of attack where desired lift coefficient is developed
CL(WB)	That portion of desired lift coefficient developed by the planform with the maximum span when two planforms are specified When one planform is specified, this is the desired lift coefficient.

CDI AT CL(WB)	Induced drag coefficient for lift coefficient in previous item When two planforms are specified, this is the induced drag coefficient of only the planform with the maximum span. This result is based on the far-field solution (see Part III, Section 3).
CDI/(CL(WB)**2)	Induced drag parameter computed from the two previous items
1/(PI*AR)	Induced drag parameter for an elliptic load distribution based on reference aspect ratio
CL ALPHA	$\left\{\begin{array}{l}\text{Lift-curve slope per radian}\\ \text{Lift-curve slope per degree}\end{array}\right.$
CL(TWIST)	Lift coefficient due to twist and/or camber at zero angle of attack
ALPHA AT CL = 0	Angle of attack at zero lift in degrees Nonzero only when twist and/or camber is specified
Y CP	Spanwise distance in fraction of semispan from root chord to center of pressure on left wing panel
CM/CL	Longitudinal stability parameter based on a moment center about $\hat{Y}$-axis
CMO	Pitching-moment coefficient at $C_L = 0$

At each chordwise row of horseshoe vortices the following data are presented:

2Y/B	Location of midpoint of each chordwise row of horseshoe vortices in fraction of semispan locations are listed sequentially from near left wing tip toward root

The next two columns of data describe the additional (or angle of attack) wing loading at a lift coefficient of 1 (based on the total lift achieved and the true wing area).

SL COEF	Span-load coefficient, $c_l c / C_L c_{av}$
CL RATIO	Ratio of local lift to total lift, c_l / C_L
C RATIO	Ratio of local chord to average chord, c / c_{av}
LOAD DUE TO TWIST	Distribution of span-load coefficient due to twist and camber at 0° angle of attack

ADD. LOAD AT CL =	Distribution of additional span-load coefficient required to produce zero lift when combined with lift due to twist and camber This distribution is computed at $C_{L,tc}$.
BASIC LOAD AT CL = 0	Basic span-load-coefficient distribution at zero lift coefficient These data are the sum of the previous two columns of data.
SPAN LOAD AT DESIRED CL	Distribution of combination of basic span load and additional span-load coefficients at desired C_L
SL COEF FROM CHORD BD VOR	Portion of span-load coefficient due to lift along chordwise bound vortices averaged at horseshoe vortex midspan

In addition, at each chordwise row of horseshoe vortices, the following data are presented for induced drag, leading-edge thrust, and suction coefficient characteristics computed at an angle of attack of 1 rad from a near-field solution for the additional loading (see Part III, Section 3).

L. E. SWEEP ANGLE	Leading-edge sweep angle in degrees
CDII C/2B	Nondimensional section induced-drag-coefficient term
CT C/2B	Nondimensional section leading-edge thrust-coefficient term
CS C/2B	Nondimensional section leading-edge suction-coefficient term
CDII	Contribution to total drag coefficient from each spanwise row of horseshoe vortices, $c_{d,ii}(2s \cos \phi)/(q_\infty S_{ref})$
CT	Contribution to total leading-edge thrust coefficient from each spanwise row of horseshoe vortices, $c_t(2s \cos \phi)/(q_\infty S_{ref})$
CS	Contribution to total suction coefficient from each spanwise row of horseshoe vortices, $c_s(2s \cos \phi)/(q_\infty S_{ref})$

Finally, the total coefficient values are listed.

CDII/CL**2	Induced-drag parameter computed from near-field solution
CT	Leading-edge thrust coefficient computed at 1 rad angle of attack
CS	Leading-edge suction coefficient computed at 1 rad angle of attack
THIS CASE IS FINISHED	End of output for a particular configuration

For the case where PTEST is 1, all the foregoing aerodynamic output data are omitted and only CLP is printed.

For the case where QTEST is 1, all the foregoing aerodynamic output data are omitted and only CMQ and CLQ are printed.

APPENDIX C

SAMPLE CASES

Input data, sketches, and output data for the sample cases described on page 34 are presented in the following order:

Sample case	Configuration	Item	Page
1	70	Input data	46
1	70	Sketch	47
2,3,4	13,113,110	Input data	48
2,3,4	13,113,110	Sketch	49
5,6,7	15,215,315	Input data	50
5,6,7	15,215,315	Sketch	51
1	70	Output data	52
2	13	Output data	59
3	113	Output data	67
4	110	Output data	74
5	15	Output data	80
6	215	Output data	86
7	315	Output data	89

These sample cases reflect the fact that the central processing time for a case is generally proportional to the square of the number of horseshoe vortices used to represent the left half of a planform. Some typical times for the sample cases with a Control Data 6600 computer system are as follows:

Sample case	Number of horseshoe vortices	Time, sec
1	100	62.6
2	89	28.7
3	89	28.7
4	52	7.4
5	61	12.1
6	57	9.0
7	96	34.8

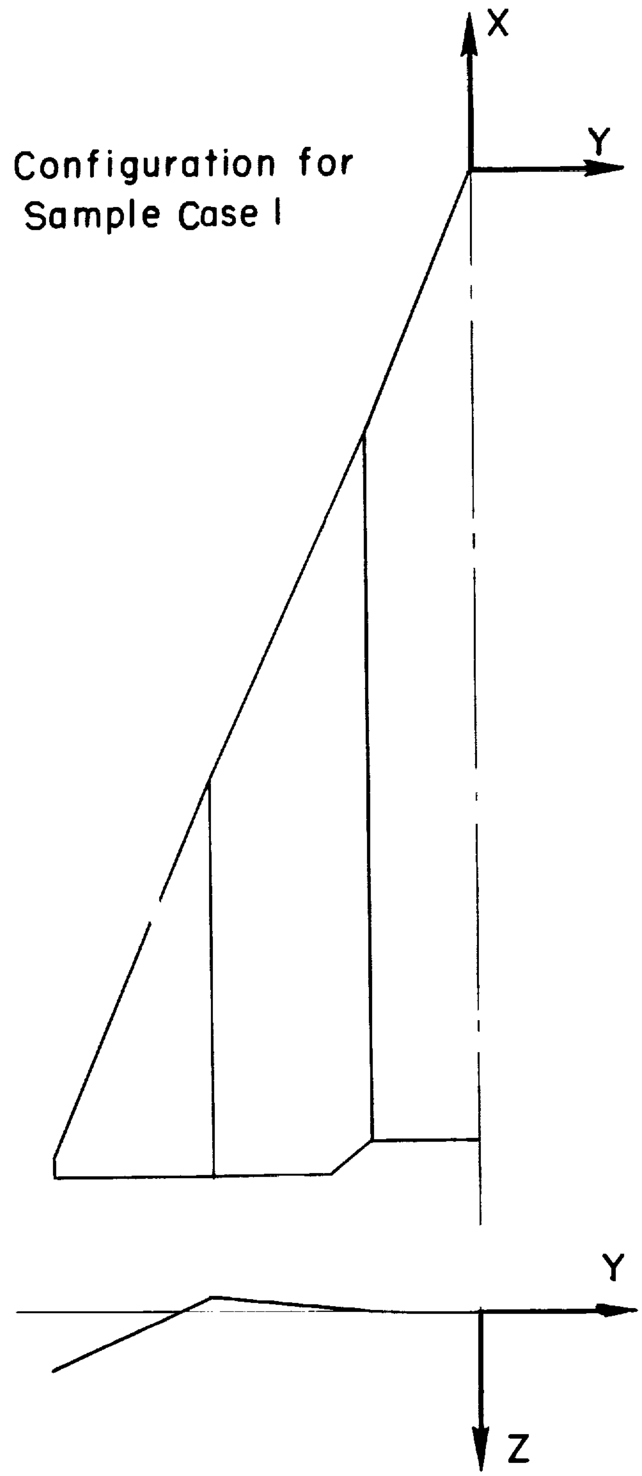
Input Data for Sample Case I

Group One Data

1.	1.	78.53166	6297.15
8.	0.	0.	0.
0.	0.	0.	1.
-30.72	-12.32	5.	1.
-73.85	-31.84	25.	1.
-119.313	-50.56	0.	1.
-121.5	-50.56	25.	1.
-121.5	-31.84	5.	1.
-121.5	-17.19	5.	1.
-117.7	-12.32	0.	1.
-117.7	0.		
70. 10.	10.5 .7	.2 0.	0. 1.

Group Two Data

-.03	-.03	-.03	-.03	-.03	-.03	-.03	-.03
-.03	-.03	-.036	-.035	-.036	-.036	-.036	-.036
-.036	-.036	-.036	-.036	-.038	-.038	-.038	-.038
-.039	-.038	-.038	-.038	-.038	-.038	-.039	-.039
-.039	-.039	-.039	-.039	-.039	-.039	-.039	-.039
-.050	-.050	-.050	-.041	-.041	-.041	-.041	-.020
-.020	-.020	-.048	-.048	-.048	-.021	-.021	-.021
-.021	0.0	0.0	0.0	-.042	-.035	-.035	-.006
-.006	-.006	-.006	0.0	0.0	0.0	-.043	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-.041	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	-.004	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0				


X
Y
Configuration for
Sample Case I
Y
Z

Input Data for Sample Cases 2,3,and 4

```
  2.          3.         10.95      621.792
  9.         -0.3       -10.1         0.
 48.3         0.          0.          1.
 37.8       - 1.9         0.          1.
 30.6       - 2.9         0.          1.
17.67222    - 5.3         0.          1.
  2.5       -12.8         0.          2.
 -5.7       -30.6         0.          2.
-11.0       -30.6         0.          2.
- 8.2       -12.8         0.          1.
-10.5       - 5.3         0.          1.
-10.5         0.
  6.          0.          0.          0.
-10.5         0.          0.          1.
-10.5       - 5.3         0.          1.
-17.35      - 5.3         0.          1.
-30.48852   -14.5         0.          1.
-34.84463   -14.5         0.          1.
-29.53301   - 5.3         0.          1.
-29.53301     0.
 13.   0.   15.    0.    1.    0.    0.    0.    24.734    0.
 24.
  3.          3.          3.          3.          3.          3.          3.          3.
  3.          4.          4.          4.          4.          6.          8.          8.
  3.          3.          3.          3.          3.          3.          3.          3.
113.   0.   15.    0.    1.    0.    0.    0.    24.734    1.
 24.
  3.          3.          3.          3.          3.          3.          3.          3.
  3.          4.          4.          4.          4.          6.          8.          8.
  3.          3.          3.          3.          3.          3.          3.          3.
 -.17453    -.17453     -.17453     -.17453     -.17453     -.17453     -.17453     -.17453
 -.17453    -.17453     -.17453     -.17453     -.17453     -.17453     -.17453      0.
   0.          0.          0.          0.          0.          0.          0.          0.
110.   2.   15.    0.    1.    0.    0.    0.    72.    0.
```

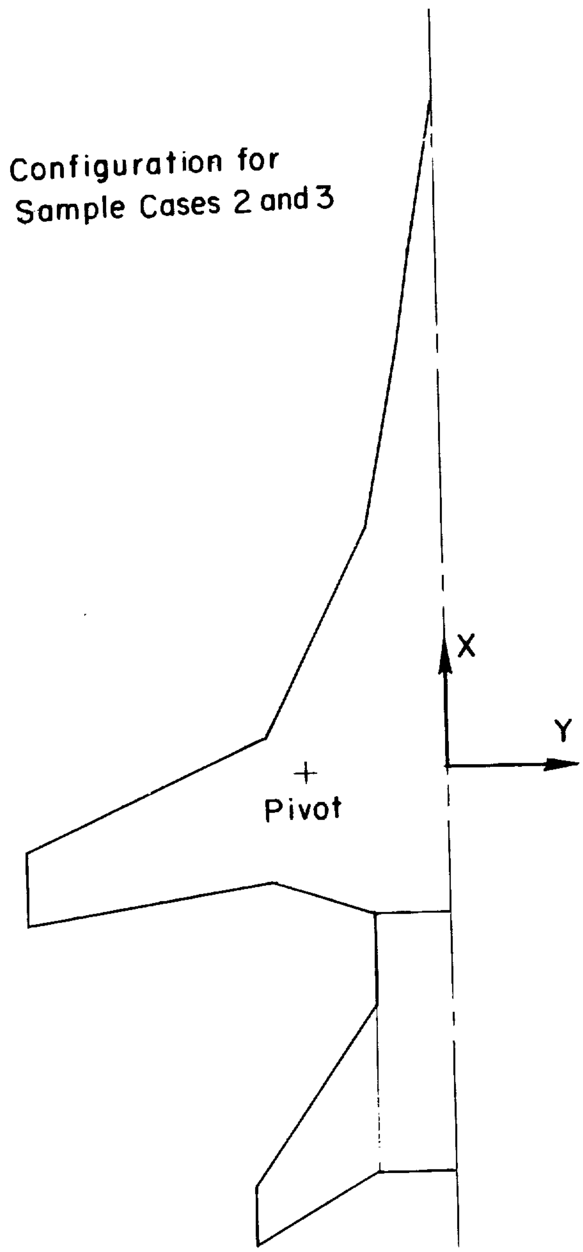
Group One Data

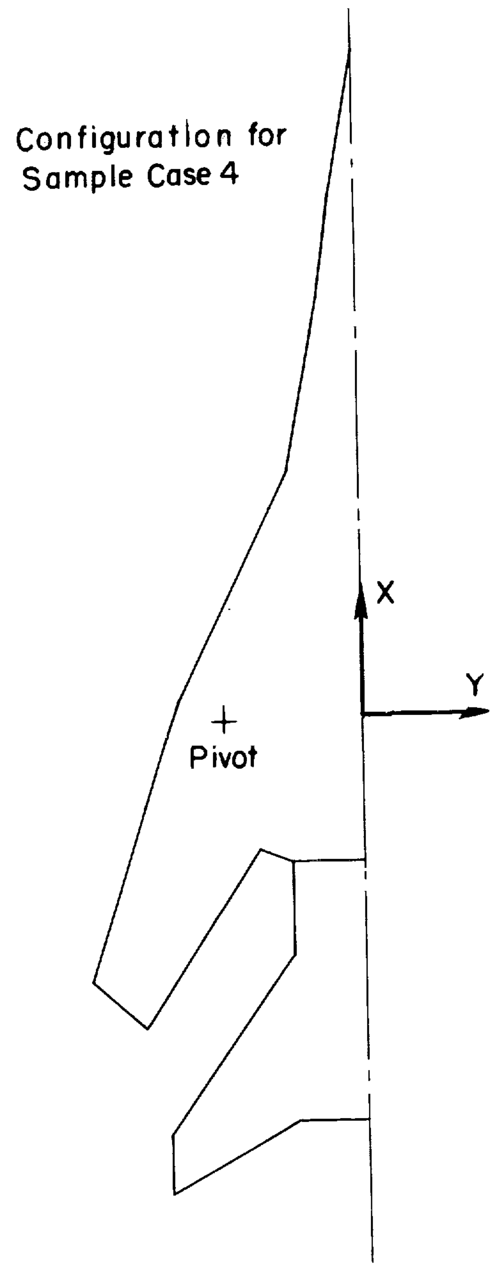
Group Two Data for:

Sample Case 2

Sample Case 3

Sample Case 4


Configuration for
Sample Cases 2 and 3
X
Y
Pivot


Configuration for
Sample Case 4
X
Y
Pivot

Input Data for Sample Cases 5,6 and 7

Group One Data

```
   1.0        3.        19.155    320.688
  14.0        0.         0.         0.
  33.325      0.00       0.         1.
  25.905      -.975      0.         1.
  18.105      -.975      0.         1.
  -6.445     -8.03       0.         1.
 -10.795     -9.75       0.         1.
 -14.345    -11.412      0.         1.
 -15.725    -11.412      0.         1.
 -14.745     -9.75       0.         1.
 -13.655     -8.03       0.         1.
 -12.095     -5.85       0.         1.
 -11.095     -4.275      0.         1.
 -10.545     -2.675      0.         1.
 -10.445      -.975      0.         1.
 -12.425      -.975      0.         1.
 -12.425      0.00
```

Group Two Data for:

Sample Case 5

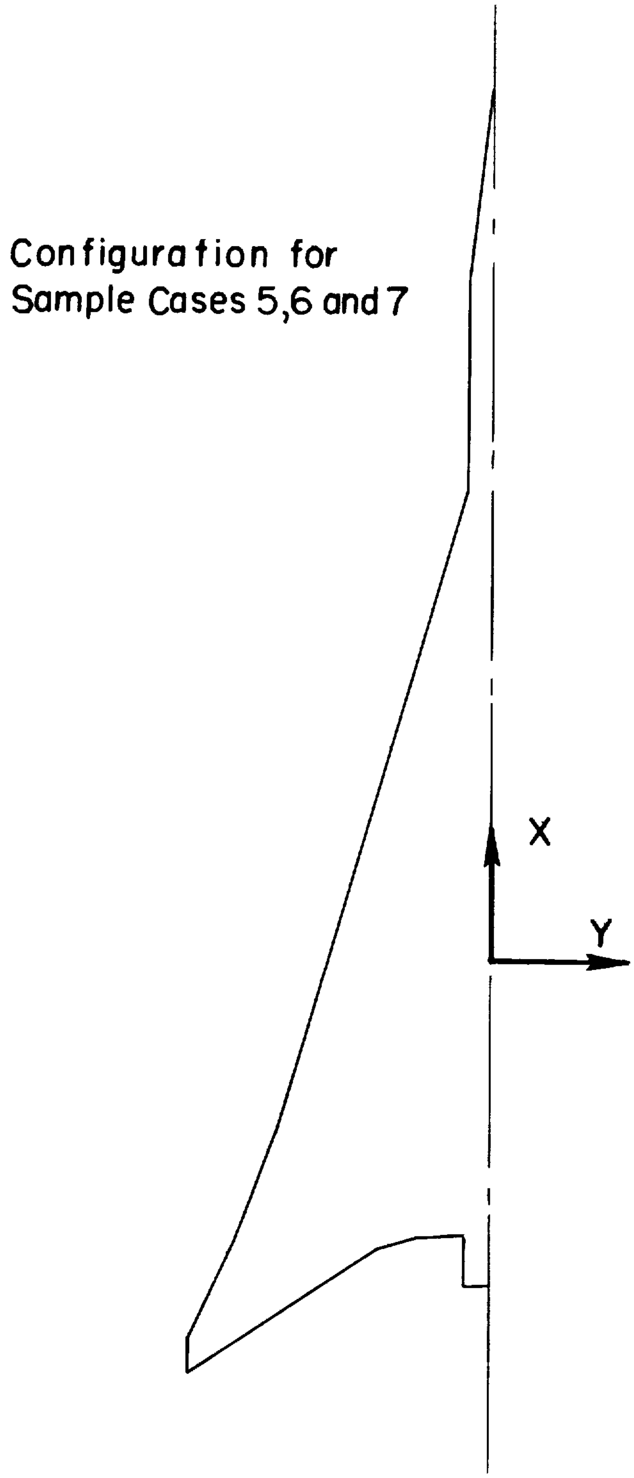
```
 015.    0.     4.   .54   11.    0.    0.    1.
     7.
  4.       8.       9.       9.       9.       9.       13.
  .1396    .146     .1705    .1897    .0847    .0760    .0975    .1326
  .1339    .1343    .1343    .1343   -.0305    .019     .0505    .0665
  .083     .096     .098     .116     .119    -.0305    .0137    .0470
  .0570    .0790    .084     .085     .091     .098    -.011     .0270
  .0504    .0725    .071     .092     .101     .098     .0755    .0118
  .0616    .070     .0832    .098     .0936    .0830    .0684    .0534
  .0       .0       .047     .103     .103     .103     .103     .103
  .103     .087     .087     .087     .087
```

Sample Case 6

```
 215.    3.   18.   .54    1.    1.    0.    0.
```

Sample Case 7

```
 315.   12.    8.   .54    1.    0.    1.    0.
```


Configuration for
Sample Cases 5,6 and 7
X
Y

GEOMETRY DATA

REFERENCE PLANFORM HAS 8 CURVES

ROOT CHORD HEIGHT = 0.00000 VARIABLE SWEEP PIVOT POSITION X(S) = 0.00000 Y(S) = 0.00000

BREAK POINTS FOR THE REFERENCE PLANFORM

POINT	X REF	Y REF	SWEEP ANGLE	DIHEDRAL ANGLE	MOVE CODE
1	0.00000	0.00000	68.14716	0.00000	1
2	-30.72000	-12.32000	65.64920	5.00000	1
3	-73.85000	-31.84000	67.61993	25.00000	1
4	-119.31300	-50.56000	90.00000	0.00000	1
5	-121.50000	-50.56000	0.00000	25.00000	1
6	-121.50000	-31.84000	0.00000	5.00000	1
7	-121.50000	-17.19000	37.96447	5.00000	1
8	-117.70000	-12.32000	0.00000	0.00000	1
9	-117.70000	0.00000			

CONFIGURATION NO. 70

CURVE 1 IS SWEPT 68.14716 DEGREES ON PLANFORM 1

BREAK POINTS FOR THIS CONFIGURATICN

POINT	X	Y	Z	SWEEP ANGLE	CIHEDRAL ANGLE	MOVE CODE
1	0.00000	0.00000	0.00000	68.14716	0.00000	1
2	-30.72000	-12.32000	0.00000	65.64920	5.00000	1
3	-73.85000	-31.84000	-1.70778	67.61993	25.00000	1
4	-119.31300	-50.56000	-10.43706	90.00000	0.00000	1
5	-121.50000	-50.56000	-10.43706	0.00000	25.00000	1
6	-121.50000	-31.84000	-1.70778	0.00000	5.00000	1
7	-121.50000	-17.19000	-.42607	37.96447	5.00000	1
8	-117.70000	-12.32000	0.00000	0.00000	0.00000	1
9	-117.70000	0.00000	0.00000			

100 HORSESHOE VORTICES USED ON THE LEFT HALF OF THE CONFIGURATION

PLANFORM	TOTAL	SPANWISE
1	100	10

10 HORSESHOE VORTICES IN EACH CHORDWISE ROW

AERODYNAMIC DATA

CONFIGURATION NO. 70

STATIC LONGITUDINAL AERODYNAMIC COEFFICIENTS ARE COMPUTED

X C/4	X 3C/4	Y	Z	S	C/4 SWEEP ANGLE	DIHEDRAL ANGLE	LOCAL ALPHA IN RADIANS	DELTA CP AT DESIRED CL = .20000
-113.99551	-114.38035	-48.29122	-9.37911	2.50332	71.59378	25.00000	-.03000	10.76098
-114.76520	-115.15004	-48.29122	-9.37911	2.50332	69.65482	25.00000	-.03000	.68904
-115.53489	-115.91974	-48.29122	-9.37911	2.50332	67.28317	25.00000	-.03000	.96517
-116.30458	-116.68943	-48.29122	-9.37911	2.50332	64.32748	25.00000	-.03000	.40407
-117.07427	-117.45912	-48.29122	-9.37911	2.50332	60.56514	25.00000	-.03000	.24687
-117.84396	-118.22881	-48.29122	-9.37911	2.50332	55.66429	25.00000	-.03000	.16326
-118.61366	-118.99850	-48.29122	-9.37911	2.50332	49.13303	25.00000	-.03000	.06129
-119.38335	-119.76819	-48.29122	-9.37911	2.50332	40.28361	25.00000	-.03000	.52524
-120.15304	-120.53789	-48.29122	-9.37911	2.50332	28.34077	25.00000	-.03000	.11729
-120.92273	-121.30758	-48.29122	-9.37911	2.50332	13.01562	25.00000	-.03000	.03122
-103.25117	-104.18701	-43.75365	-7.26321	2.50332	71.59378	25.00000	-.03600	5.24070
-105.12285	-106.05868	-43.75365	-7.26321	2.50332	69.65482	25.00000	-.03600	.27091
-106.99452	-107.93036	-43.75365	-7.26321	2.50332	67.28317	25.00000	-.03600	.06305
-108.86620	-109.80203	-43.75365	-7.26321	2.50332	64.32748	25.00000	-.03600	.01407
-110.73787	-111.67371	-43.75365	-7.26321	2.50332	60.56514	25.00000	-.03600	-.00335
-112.60954	-113.54538	-43.75365	-7.26321	2.50332	55.66429	25.00000	-.03600	-.00957
-114.48122	-115.41706	-43.75365	-7.26321	2.50332	49.13303	25.00000	-.03600	-.01305
-116.35289	-117.28873	-43.75365	-7.26321	2.50332	40.28361	25.00000	-.03600	-.01976
-118.22457	-119.16041	-43.75365	-7.26321	2.50332	28.34077	25.00000	-.03600	-.03727
-120.09624	-121.03208	-43.75365	-7.26321	2.50332	13.01562	25.00000	-.03600	-.03466
-92.50683	-93.99366	-39.21609	-5.14731	2.50332	71.59378	25.00000	-.03800	3.48887
-95.48049	-96.96732	-39.21609	-5.14731	2.50332	69.65482	25.00000	-.03800	.20148
-98.45415	-99.94098	-39.21609	-5.14731	2.50332	67.28317	25.00000	-.03800	.05310
-101.42781	-102.91464	-39.21609	-5.14731	2.50332	64.32748	25.00000	-.03800	.03308
-104.40147	-105.88830	-39.21609	-5.14731	2.50332	60.56514	25.00000	-.03800	.02909
-107.37512	-108.86195	-39.21609	-5.14731	2.50332	55.66429	25.00000	-.03800	.02460
-110.34878	-111.83561	-39.21609	-5.14731	2.50332	49.13303	25.00000	-.03800	.01711
-113.32244	-114.80927	-39.21609	-5.14731	2.50332	40.28361	25.00000	-.03800	.00590
-116.29610	-117.78293	-39.21609	-5.14731	2.50332	28.34077	25.00000	-.03800	-.01193
-119.26976	-120.75659	-39.21609	-5.14731	2.50332	13.01562	25.00000	-.03800	-.01551
-81.08796	-83.16037	-34.39365	-2.89857	2.81765	71.59378	25.00000	-.03900	2.25611
-85.23278	-87.30520	-34.39365	-2.89857	2.81765	69.65482	25.00000	-.03900	.07229
-89.37761	-91.45002	-34.39365	-2.89857	2.81765	67.28317	25.00000	-.03900	-.01846

-93.52243	-95.59485	-34.39365	-2.89857	2.81765	64.32748	25.00000	-.03900	-.02500
-97.66726	-99.73967	-34.39365	-2.89857	2.81765	60.56514	25.00000	-.03900	-.02468
-101.81208	-103.88449	-34.39365	-2.89857	2.81765	55.66429	25.00000	-.03900	-.02241
-105.95691	-108.02932	-34.39365	-2.89857	2.81765	49.13303	25.00000	-.03900	-.02120
-110.10173	-112.17414	-34.39365	-2.89857	2.81765	40.28361	25.00000	-.03900	-.03146
-114.24656	-116.31897	-34.39365	-2.89857	2.81765	28.34077	25.00000	-.03900	-.05363
-118.39138	-120.46379	-34.39365	-2.89857	2.81765	13.01562	25.00000	-.03900	-.04877
-69.66889	-72.32689	-29.34620	-1.48960	2.50332	71.59440	5.00000	-.05000	.84470
-74.98490	-77.64290	-29.34620	-1.48960	2.50332	69.65550	5.00000	-.05000	.20519
-80.30091	-82.95891	-29.34620	-1.48960	2.50332	67.28392	5.00000	-.05000	.05717
-85.61692	-88.27493	-29.34620	-1.48960	2.50332	64.32830	5.00000	-.04100	.01957
-90.93293	-93.59094	-29.34620	-1.48960	2.50332	60.56603	5.00000	-.04100	-.01286
-96.24894	-98.90695	-29.34620	-1.48960	2.50332	55.66527	5.00000	-.04100	-.02010
-101.56496	-104.22296	-29.34620	-1.48960	2.50332	49.13407	5.00000	-.04100	-.01463
-106.88097	-109.53897	-29.34620	-1.48960	2.50332	40.28465	5.00000	-.02000	.02759
-112.19698	-114.85499	-29.34620	-1.48960	2.50332	28.34165	5.00000	-.02000	-.03987
-117.51299	-120.17100	-29.34620	-1.48960	2.50332	13.01609	5.00000	-.02000	-.04024
-58.92416	-62.13317	-24.35861	-1.05324	2.50332	71.59440	5.00000	-.04800	.77496
-65.34219	-68.55121	-24.35861	-1.05324	2.50332	69.65550	5.00000	-.04800	.26596
-71.76023	-74.96924	-24.35861	-1.05324	2.50332	67.28392	5.00000	-.04800	.21138
-78.17826	-81.38728	-24.35861	-1.05324	2.50332	64.32830	5.00000	-.02100	.21071
-84.59630	-87.80531	-24.35861	-1.05324	2.50332	60.56603	5.00000	-.02100	.13162
-91.01433	-94.22335	-24.35861	-1.05324	2.50332	55.66527	5.00000	-.02100	.09786
-97.43237	-100.64139	-24.35861	-1.05324	2.50332	49.13407	5.00000	-.02100	.08204
-103.85040	-107.05942	-24.35861	-1.05324	2.50332	40.28465	5.00000	0.00000	.11332
-110.26844	-113.47746	-24.35861	-1.05324	2.50332	28.34165	5.00000	0.00000	.04262
-116.68647	-119.89549	-24.35861	-1.05324	2.50332	13.01609	5.00000	0.00000	.01587
-48.51634	-52.25909	-19.52740	-.63057	2.34633	71.59440	5.00000	-.04200	.65321
-56.00185	-59.74460	-19.52740	-.63057	2.34633	69.65550	5.00000	-.03500	.25369
-63.48735	-67.23010	-19.52740	-.63057	2.34633	67.28392	5.00000	-.03500	.19504
-70.97285	-74.71560	-19.52740	-.63057	2.34633	64.32830	5.00000	-.00600	.21768
-78.45836	-82.20111	-19.52740	-.63057	2.34633	60.56603	5.00000	-.00600	.15599
-85.94386	-89.68661	-19.52740	-.63057	2.34633	55.66527	5.00000	-.00600	.12295
-93.42936	-97.17211	-19.52740	-.63057	2.34633	49.13407	5.00000	-.00600	.10167
-100.91487	-104.65762	-19.52740	-.63057	2.34633	40.28465	5.00000	0.00000	.10118
-108.40037	-112.14312	-19.52740	-.63057	2.34633	28.34165	5.00000	0.00000	.06194
-115.88587	-119.62862	-19.52740	-.63057	2.34633	13.01609	5.00000	0.00000	.03011
-38.18770	-42.36269	-14.75500	-.21303	2.44430	71.74858	5.00000	-.04300	.52346
-46.53768	-50.71267	-14.75500	-.21303	2.44430	70.55766	5.00000	0.00000	.28209
-54.88766	-59.06265	-14.75500	-.21303	2.44430	69.20780	5.00000	0.00000	.18917
-63.23764	-67.41263	-14.75500	-.21303	2.44430	67.66674	5.00000	0.00000	.16391
-71.58762	-75.76261	-14.75500	-.21303	2.44430	65.85356	5.00000	0.00000	.15388
-79.93760	-84.11259	-14.75500	-.21303	2.44430	63.83584	5.00000	0.00000	.13062
-88.28758	-92.46257	-14.75500	-.21303	2.44430	61.42597	5.00000	0.00000	.10847
-96.63756	-100.81255	-14.75500	-.21303	2.44430	58.57625	5.00000	0.00000	.09150
-104.98754	-109.16253	-14.75500	-.21303	2.44430	55.17298	5.00000	0.00000	.06953
-113.33752	-117.51251	-14.75500	-.21303	2.44430	51.07013	5.00000	0.00000	.03956
-26.80850	-31.46960	-9.81668	0.00000	2.50332	73.63013	0.00000	-.04100	.38880
-36.13070	-40.79181	-9.81668	0.00000	2.50332	71.87593	0.00000	0.00000	.28388
-45.45291	-50.11401	-9.81668	0.00000	2.50332	69.71822	0.00000	0.00000	.20770
-54.77511	-59.43622	-9.81668	0.00000	2.50332	67.00859	0.00000	0.00000	.17523

-64.09732	-68.75842	-9.81668	0.00000	2.50332	63.52262	0.00000	0.00000	.15768
-73.41952	-78.08063	-9.81668	0.00000	2.50332	58.91214	0.00000	0.00000	.14335
-82.74173	-87.40283	-9.81668	0.00000	2.50332	52.62972	0.00000	0.00000	.12448
-92.06394	-96.72504	-9.81668	0.00000	2.50332	43.83659	0.00000	0.00000	.10525
-101.38614	-106.04724	-9.81668	0.00000	2.50332	31.42624	0.00000	0.00000	.08388
-110.70835	-115.36945	-9.81668	0.00000	2.50332	14.67456	0.00000	0.00000	.05402
-11.83250	-17.26160	-3.65668	0.00000	3.65668	73.63C13	0.00000	-.00400	.30784
-22.69070	-28.11981	-3.65668	0.00000	3.65668	71.87593	0.00000	0.00000	.19539
-33.54891	-38.97801	-3.65668	0.00000	3.65668	69.71822	0.00000	0.00000	.18407
-44.40711	-49.83622	-3.65668	0.00000	3.65668	67.0C859	0.00000	0.00000	.17494
-55.26532	-60.69442	-3.65668	0.00000	3.65668	63.52262	0.00000	0.00000	.16152
-66.12352	-71.55263	-3.65668	0.00000	3.65668	58.91214	0.00000	0.00000	.14827
-76.98173	-82.41083	-3.65668	0.00000	3.65668	52.62972	0.00000	0.00000	.13245
-87.83994	-93.26904	-3.65668	0.00000	3.65668	43.83659	0.00000	0.00000	.11221
-98.69814	-104.12724	-3.65668	0.00000	3.65668	31.42624	0.00000	0.00000	.08876
-109.55635	-114.98545	-3.65668	0.00000	3.65668	14.67456	0.00000	0.00000	.05718

REF. CHORD	C AVERAGE	TRUE AREA	REFERENCE AREA	B/2	REF. AR	TRUE AR	MACH NUMBER
78.53166	60.70267	6138.25384	6297.15000	50.56000	1.62379	1.66582	.70000

COMPLETE CONFIGURATION

DESIRED CL	COMPUTED ALPHA
.20000	6.33753

WING-BODY CHARACTERISTICS

LIFT	INDUCED DRAG (FAR FIELD SOLUTION)	
CL(WB)	CDI AT CL(WB)	CDI/(CL(WB)**2) (1/(PI*AR) = .19603)
.20000	.C1112	.27791

COMPLETE CONFIGURATION CHARACTERISTICS

CL ALPHA PER RADIAN	CL ALPHA PER DEGREE	CL(TWIST)	ALPHA AT CL=0	Y CP	CM/CL	CMO
2.02242	.03530	-.02370	.67146	-.45842	-.91575	.00186

ADDITIONAL LOADING
WITH CL BASED ON S(TRUE)

STATION	2Y/B	SL COEF	CL RATIO	C RATIO	LOAD DUE TO TWIST	ADD. LOAD AT CL= -.02370	BASIC LOAD AT CL=0	SPAN LOAD AT DESIRED CL	SL COEF FROM CHORD BD VDR
1	-.95513	.85668	6.75633	.12680	-.01954	-.02C83	.00129	.17706	.01397
2	-.86538	.86973	2.82072	.30833	-.03090	-.02115	-.00976	.16869	-.20203
3	-.77563	.97536	1.99105	.48987	-.03642	-.C2372	-.01271	.18741	-.19589
4	-.68025	.78127	1.14420	.68281	-.03708	-.C1900	-.01808	.14221	-.45246
5	-.58042	.52278	.59695	.87575	-.03008	-.01271	-.01736	.08990	-.45641
6	-.48178	.99493	.94102	1.05729	-.02254	-.02419	.00165	.20579	-.11537
7	-.38622	1.10331	.89471	1.23314	-.01971	-.C2683	.00712	.23349	-.05280
8	-.29133	1.12860	.82047	1.37555	-.01798	-.02744	.00946	.24102	.00022
9	-.19416	1.22765	.79940	1.53572	-.01694	-.C2985	.01291	.26480	.01410
10	-.07232	1.28911	.72067	1.78375	-.01633	-.03134	.01502	.27951	.00155

INDUCED DRAG, LEADING EDGE THRUST AND SUCTION COEFFICIENT CHARACTERISTICS
COMPUTED AT ONE RADIAN ANGLE OF ATTACK FROM A NEAR FIELD SOLUTION

			SECTION COEFFICIENTS			CONTRIBUTIONS TO TOTAL COEF. FROM EACH SPANWISE ROW		
STATION	2Y/B	L. E. SWEEP ANGLE	CDII C/2B	CT C/2B	CS C/2B	CDII	CT	CS
1	-.95513	67.61993	.18226	.35124	.92250	.02656	.05119	.13443
2	-.86538	67.61993	.12070	.42092	1.10551	.01759	.06134	.16111
3	-.77563	67.61993	.17794	.42946	1.12794	.02593	.06259	.16437
4	-.68025	67.61993	.07957	.40696	1.06883	.01305	.06675	.17532
5	-.58042	65.64920	-.13589	.46145	1.11915	-.02177	.07392	.17927
6	-.48178	65.64920	.19733	.42226	1.02410	.03161	.06764	.16404
7	-.38622	65.64920	.32004	.36704	.89017	.04805	.05511	.13365
8	-.29183	65.64920	.39901	.30382	.73686	.06241	.04752	.11525

9	-.19416	68.14716	.51997	.24454	.65698	.08361	.03932	.10564
10	-.07232	68.14716	.64560	.15719	.42229	.15164	.03692	.09919

TOTAL COEFFICIENTS

COII/CL**2 =   .21450   CT=   1.12457   CS=   2.86453

THIS CASE IS FINISHED

GEOMETRY DATA

FIRST REFERENCE PLANFORM HAS 9 CURVES

ROOT CHORD HEIGHT = 0.000C0 VARIABLE SWEEP PIVOT POSITION X(S) = -.30000 Y(S) = -10.10000

BREAK POINTS FOR THE REFERENCE PLANFORM

POINT	X REF	Y REF	SWEEP ANGLE	DIHEDRAL ANGLE	MOVE CODE
1	48.30000	0.00000	79.74318	C.00000	1
2	37.80000	-1.90000	82.09284	C.0C000	1
3	30.60000	-2.90000	79.48296	C.CC000	1
4	17.67222	-5.30000	63.69569	C.00000	1
5	2.50000	-12.80000	24.73430	C.CC000	2
6	-5.70000	-30.60000	90.00000	C.0C000	2
7	-11.00000	-30.60000	8.93957	C.00000	2
8	-8.20000	-12.80000	-17.04903	C.00000	1
9	-10.50000	-5.30000	0.00000	0.00000	1
10	-10.50000	0.00000			

SECOND REFERENCE PLANFORM HAS 6 CURVES

ROOT CHORD HEIGHT = 0.00000 VARIABLE SWEEP PIVOT POSITION X(S) = 0.00000 Y(S) = 0.00000

BREAK POINTS FOR THE REFERENCE PLANFCRM

POINT	X REF	Y REF	SWEEP ANGLE	DIHEDRAL ANGLE	MOVE CODE
1	-10.50000	0.00000	0.00000	C.00000	1
2	-10.50000	-5.30000	90.00000	C.00000	1
3	-17.35000	-5.30000	54.99910	C.CC000	1
4	-30.48852	-14.50000	90.00000	C.00000	1
5	-34.84463	-14.50000	29.99999	C.00000	1
6	-29.53301	-5.30000	0.00000	C.C0000	1
7	-29.53301	0.00000			

CONFIGURATION NO. 13

CURVE 5 IS SWEPT 24.73400 DEGREES ON PLANFORM 1

CURVE 1 IS SWEPT 0.00000 DEGREES ON PLANFORM 2

BREAK POINTS FOR THIS CONFIGURATICN

POINT	X	Y	Z	SWEEP ANGLE	DIHEDRAL ANGLE	MOVE CODE
1	48.30000	0.00000	0.00000	79.74318	0.00000	1
2	37.80000	-1.90000	0.00000	82.09284	0.00000	1
3	30.60000	-2.90000	0.00000	79.48296	0.00000	1
4	17.67222	-5.30000	0.00000	63.69569	0.00000	1
5	2.50000	-12.80000	0.00000	24.73430	0.00000	2
6	1.71685	-14.50000	0.00000	24.73430	0.00000	2
7	-5.70000	-30.60000	0.00000	90.00000	0.00000	2
8	-11.00000	-30.60000	0.00000	8.93957	0.00000	2
9	-8.20000	-12.80000	0.00000	-17.04903	0.00000	1
10	-10.50000	-5.30000	0.00000	0.00000	0.00000	1
11	-10.50000	0.00000	0.00000			

SECOND PLANFORM BREAK POINTS

POINT	X	Y	Z	SWEEP ANGLE	DIHEDRAL ANGLE	MOVE CODE
1	-10.50000	0.00000	0.00000	0.00000	0.00000	1
2	-10.50000	-1.90000	0.00000	0.00000	0.00000	1
3	-10.50000	-2.90000	0.00000	0.00000	0.00000	1
4	-10.50000	-5.30000	0.00000	90.00000	0.00000	1
5	-17.35000	-5.30000	0.00000	54.99910	0.00000	1
6	-28.06075	-12.80000	0.00000	54.99910	0.00000	1
7	-30.48852	-14.50000	0.00000	90.00000	0.00000	1
8	-34.84463	-14.50000	0.00000	29.99999	0.00000	1
9	-29.53301	-5.30000	0.00000	0.00000	0.00000	1
10	-29.53301	0.00000	0.00000			

89 HORSESHOE VORTICES USED ON THE LEFT HALF OF THE CONFIGURATION

PLANFORM	TOTAL	SPANWISE
1	65	16
2	24	8

APPENDIX C

TABLE OF HORSESHOE VORTICES IN EACH CHORDWISE ROW (FROM TIP TO ROOT BEGINNING WITH FIRST PLANFORM)

3	3	3	3	3	3	3	3	3	4	4	4	4	6	8	8	3	3	3	3	3	3	3	3

AERODYNAMIC DATA

CONFIGURATION NO. 13

STATIC LONGITUDINAL AERODYNAMIC COEFFICIENTS ARE COMPUTED

X C/4	X 3C/4	Y	Z	S	C/4 SWEEP ANGLE	DIHEDRAL ANGLE	LOCAL ALPHA IN RADIANS	DELTA CP AT DESIRED CL = 1.00000
-5.69757	-6.63247	-29.58000	0.00000	1.02000	23.52798	0.00000	0.00000	1.43972
-7.56738	-8.50228	-29.58000	0.00000	1.02000	18.48322	0.00000	0.00000	.40282
-9.43719	-10.37210	-29.58000	0.00000	1.02000	13.12385	0.00000	0.00000	.16372
-4.80936	-5.84742	-27.54000	0.00000	1.02000	23.52798	0.00000	0.00000	1.71092
-6.88547	-7.92352	-27.54000	0.00000	1.02000	18.48322	0.00000	0.00000	.58885
-8.96157	-9.99963	-27.54000	0.00000	1.02000	13.12385	0.00000	0.00000	.25600
-3.92116	-5.06236	-25.50000	0.00000	1.02000	23.52798	0.00000	0.00000	1.80567
-6.20356	-7.34476	-25.50000	0.00000	1.02000	18.48322	0.00000	0.00000	.66645
-8.48596	-9.62715	-25.50000	0.00000	1.02000	13.12385	0.00000	0.00000	.30573
-3.03296	-4.27730	-23.46000	0.00000	1.02000	23.52798	0.00000	0.00000	1.84259
-5.52165	-6.76599	-23.46000	0.00000	1.02000	18.48322	0.00000	0.00000	.70060
-8.01034	-9.25468	-23.46000	0.00000	1.02000	13.12385	0.00000	0.00000	.33088
-2.14476	-3.49225	-21.42000	0.00000	1.02000	23.52798	0.00000	0.00000	1.85475
-4.83974	-6.18723	-21.42000	0.00000	1.02000	18.48322	0.00000	0.00000	.71488
-7.53472	-8.88221	-21.42000	0.00000	1.02000	13.12385	0.00000	0.00000	.34295
-1.25655	-2.70719	-19.38000	0.00000	1.02000	23.52798	0.00000	0.00000	1.85541
-4.15783	-5.60846	-19.38000	0.00000	1.02000	18.48322	0.00000	0.00000	.71850
-7.05910	-8.50974	-19.38000	0.00000	1.02000	13.12385	0.00000	0.00000	.34773
-.36835	-1.92213	-17.34000	0.00000	1.02000	23.52798	0.00000	0.00000	1.85097
-3.47592	-5.02970	-17.34000	0.00000	1.02000	18.48322	0.00000	0.00000	.71496
-6.58348	-8.13727	-17.34000	0.00000	1.02000	13.12385	0.00000	0.00000	.34826
.47196	-1.17941	-15.41000	0.00000	.91000	23.52798	0.00000	0.00000	1.84674
-2.83078	-4.48214	-15.41000	0.00000	.91000	18.48322	0.00000	0.00000	.70700
-6.13351	-7.78488	-15.41000	0.00000	.91000	13.12385	0.00000	0.00000	.34749
1.23825	-.50211	-13.65000	0.00000	.85000	23.52798	0.00000	0.00000	1.83803
-2.24246	-3.98282	-13.65000	0.00000	.85000	18.48322	0.00000	0.00000	.70522
-5.72317	-7.46353	-13.65000	0.00000	.85000	13.12385	0.00000	0.00000	.34863
3.74616	2.11163	-11.78000	0.00000	1.02000	61.95744	0.00000	0.00000	1.49489
.47710	-1.15743	-11.78000	0.00000	1.02000	52.32366	0.00000	0.00000	.90041
-2.79195	-4.42648	-11.78000	0.00000	1.02000	35.47163	0.00000	0.00000	.55206
-6.06101	-7.69554	-11.78000	0.00000	1.02000	7.41473	0.00000	0.00000	.30780
7.57597	5.34739	-9.74000	0.00000	1.02000	61.95744	0.00000	0.00000	1.09666
3.11881	.89022	-9.74000	0.00000	1.02000	52.32366	0.00000	0.00000	.65565

-1.33836	-3.56694	-9.74000	0.00000	1.02000	35.47163	0.00000	0.00000	.49023
-5.79553	-8.02411	-9.74000	0.00000	1.02000	7.41473	0.00000	0.00000	.27920
11.40579	8.58315	-7.70000	0.00000	1.02000	61.95744	0.00000	0.00000	.88016
5.76051	2.93787	-7.70000	0.00000	1.02000	52.32366	0.00000	0.00000	.51836
.11524	-2.70740	-7.70000	0.00000	1.02000	35.47163	0.00000	0.00000	.42438
-5.53004	-8.35268	-7.70000	0.00000	1.02000	7.41473	0.00000	0.00000	.25934
14.61608	11.29548	-5.99000	0.00000	.69000	61.95744	0.00000	0.00000	.75223
7.97488	4.65429	-5.99000	0.00000	.69000	52.32366	0.00000	0.00000	.42980
1.33369	-1.98691	-5.99000	0.00000	.69000	35.47163	0.00000	0.00000	.38808
-5.30750	-8.62810	-5.99000	0.00000	.69000	7.41473	0.00000	0.00000	.25516
22.69294	19.80660	-4.10000	0.00000	1.20000	79.03655	0.00000	0.00000	.48132
16.92025	14.03391	-4.10000	0.00000	1.20000	76.80254	0.00000	0.00000	.38170
11.14757	8.26123	-4.10000	0.00000	1.20000	73.45675	0.00000	0.00000	.37379
5.37488	2.48854	-4.10000	0.00000	1.20000	67.94972	0.00000	0.00000	.35705
-.39780	-3.28414	-4.10000	0.00000	1.20000	57.52312	0.00000	0.00000	.33202
-6.17049	-9.05683	-4.10000	0.00000	1.20000	33.95325	0.00000	0.00000	.23155
32.80312	30.00937	-2.40000	0.00000	.50000	81.84115	0.00000	0.00000	.29726
27.21562	24.42187	-2.40000	0.00000	.50000	80.65242	0.00000	0.00000	.25371
21.62812	18.83437	-2.40000	0.00000	.50000	79.08315	0.00000	0.00000	.27117
16.04062	13.24687	-2.40000	0.00000	.50000	76.83421	0.00000	0.00000	.30165
10.45312	7.65937	-2.40000	0.00000	.50000	73.49564	0.00000	0.00000	.30187
4.86563	2.07188	-2.40000	0.00000	.50000	67.99930	0.00000	0.00000	.28497
-.72187	-3.51562	-2.40000	0.00000	.50000	57.58769	0.00000	0.00000	.31164
-6.30937	-9.10312	-2.40000	0.00000	.50000	34.01935	0.00000	0.00000	.23324
41.37656	38.02969	-.95000	0.00000	.95000	79.41967	0.00000	0.00000	.22471
34.68281	31.33594	-.95000	0.00000	.95000	77.89558	0.00000	0.00000	.14330
27.98906	24.64219	-.95000	0.00000	.95000	75.86890	0.00000	0.00000	.17640
21.29531	17.94844	-.95000	0.00000	.95000	73.05078	0.00000	0.00000	.23506
14.60156	11.25469	-.95000	0.00000	.95000	68.89183	0.00000	0.00000	.29516
7.90781	4.56094	-.95000	0.00000	.95000	62.23737	0.00000	0.00000	.30966
1.21406	-2.13281	-.95000	0.00000	.95000	50.40208	0.00000	0.00000	.29423
-5.47969	-8.82656	-.95000	0.00000	.95000	27.38832	0.00000	0.00000	.21516

SECOND PLANFORM HORSESHOE VORTEX DESCRIPTIONS

-29.69791	-30.54445	-13.65000	0.00000	.85000	53.61688	0.00000	0.00000	.58628
-31.39099	-32.23753	-13.65000	0.00000	.85000	47.03335	0.00000	0.00000	.17644
-33.08407	-33.93061	-13.65000	0.00000	.85000	38.31006	0.00000	0.00000	.06079
-27.15993	-28.27163	-11.78000	0.00000	1.02000	53.61688	0.00000	0.00000	.50960
-29.38332	-30.49501	-11.78000	0.00000	1.02000	47.03335	0.00000	0.00000	.20784
-31.60670	-32.71839	-11.78000	0.00000	1.02000	38.31006	0.00000	0.00000	.09467
-24.39124	-25.79218	-9.74000	0.00000	1.02000	53.61688	0.00000	0.00000	.40690
-27.19313	-28.59408	-9.74000	0.00000	1.02000	47.03335	0.00000	0.00000	.18322
-29.99502	-31.39597	-9.74000	0.00000	1.02000	38.31006	0.00000	0.00000	.09576
-21.62254	-23.31274	-7.70000	0.00000	1.02000	53.61688	0.00000	0.00000	.32688
-25.00294	-26.69315	-7.70000	0.00000	1.02000	47.03335	0.00000	0.00000	.15845
-28.38335	-30.07355	-7.70000	0.00000	1.02000	38.31006	0.00000	0.00000	.08813
-19.30172	-21.23439	-5.99000	0.00000	.69000	53.61688	0.00000	0.00000	.28418
-23.16705	-25.09972	-5.99000	0.00000	.69000	47.03335	0.00000	0.00000	.13514
-27.03238	-28.96505	-5.99000	0.00000	.69000	38.31006	0.00000	0.00000	.07770
-12.08608	-15.25825	-4.10000	0.00000	1.20000	0.00000	0.00000	0.00000	.09133

-18.43042	-21.60259	-4.10000	0.00000	1.20000	0.0CC00	0.00000	0.00000	.11368
-24.77476	-27.94693	-4.10000	0.00000	1.20000	0.0C000	0.00000	0.00000	.09166
-12.08608	-15.25825	-2.40000	0.00000	.50000	0.0C000	0.00000	0.00000	.10919
-18.43042	-21.60259	-2.40000	0.00000	.50000	0.00000	0.00000	0.00000	.10639
-24.77476	-27.94693	-2.40000	0.00000	.50000	0.00000	0.00000	0.00000	.08311
-12.08608	-15.25825	-.95000	0.00000	.95000	0.C0000	0.00000	0.00000	.12157
-18.43042	-21.60259	-.95000	0.00000	.95000	0.00000	0.00000	0.00000	.10288
-24.77476	-27.94693	-.95000	0.00000	.95000	0.00000	0.C0000	0.00000	.07826

REF. CHORD	C AVERAGE	TRUE AREA	REFERENCE AREA	B/2	REF. AR	TRUE AR	MACH NUMBER
1C.95000	22.70253	1389.39479	621.79200	30.60000	6.02362	2.69573	0.00000

COMPLETE CONFIGURATION

DESIRED CL	COMPUTED ALPHA
1.00000	10.52322

WING-BODY CHARACTERISTICS

LIFT	INDUCED DRAG (FAR FIELD SOLUTION)	
CL(WB)	CDI AT CL(WB)	CDI/(CL(WB)**2) (1/(PI*AR) = .05284)
.91431	.04464	.05340

COMPLETE CONFIGURATION CHARACTERISTICS

CL ALPHA PER RADIAN	CL ALPHA PER DEGREE	CL(TWIST)	ALPHA AT CL=0	Y CP	CM/CL	CMO
5.44470	.09503	0.00000	-0.00000	-.40193	.05780	0.00000

ADDITIONAL LOADING WITH CL BASED ON S(TRUE)

STATION	2Y/B	SL COEF	CL RATIO	C RATIO	LOAD DUE TO TWIST	ADD. LOAD AT CL= 0.00000	BASIC LOAD AT CL=0	SPAN LOAD AT DESIRED CL	SL COEF FROM CHORD BD VOR
1	-.96667	.36923	1.49433	.24708	0.00000	0.00000	0.00000	.16524	0.00000
2	-.90000	.52225	1.90362	.27434	0.00000	0.00000	0.00000	.23372	0.00000
3	-.83333	.62403	2.06904	.30160	0.00000	0.00000	0.00000	.27927	0.00000
4	-.76667	.70400	2.14071	.32687	0.00000	0.00000	0.00000	.31506	0.00000
5	-.70000	.77257	2.16939	.35613	0.00000	0.00000	0.00000	.34575	0.00000
6	-.63333	.83430	2.17614	.38339	0.00000	0.00000	0.00000	.37337	0.00000
7	-.56667	.89134	2.17059	.41065	0.00000	0.00000	0.00000	.39990	0.00000
8	-.50359	.94311	2.16093	.43644	0.00000	0.00000	0.00000	.42207	0.00000
9	-.44608	.99073	2.15397	.45995	0.00000	0.00000	0.00000	.44338	0.00000
10	-.38497	1.04737	1.81842	.57598	0.00000	0.00000	0.00000	.46873	0.00000
11	-.31830	1.10628	1.40871	.78532	0.00000	0.00000	0.00000	.49509	0.00000
12	-.25163	1.15697	1.16319	.99465	0.00000	0.00000	0.00000	.51778	0.00000
13	-.19575	1.19311	1.01965	1.17012	0.00000	0.00000	0.00000	.53395	0.00000
14	-.13399	1.22580	.80346	1.52565	0.00000	0.00000	0.00000	.54858	0.00000
15	-.07843	1.24042	.62999	1.96894	0.00000	0.00000	0.00000	.55512	0.00000
16	-.03105	1.24762	.52893	2.35877	0.00000	0.00000	0.00000	.55835	0.00000

CONTRIBUTION OF THE SECOND PLANFORM TO SPAN LOAD DISTRIBUTION

STATION	2Y/B	SL COEF	CL RATIO	C RATIO	LOAD DUE TO TWIST	ADD. LOAD AT CL= 0.00000	BASIC LOAD AT CL=0	SPAN LOAD AT DESIRED CL	SL COEF FROM CHORD BD VOR
17	-.44608	.13723	.61338	.22373	0.00000	0.00000	0.00000	.06141	0.00000
18	-.38497	.17772	.60488	.29381	0.00000	0.00000	0.00000	.07953	0.00000
19	-.31830	.18915	.51087	.37025	0.00000	0.00000	0.00000	.08465	0.00000
20	-.25163	.19080	.42713	.44670	0.00000	0.00000	0.00000	.08539	0.00000
21	-.19575	.18909	.37020	.51078	0.00000	0.00000	0.00000	.08462	0.00000
22	-.13399	.18525	.22097	.83837	0.00000	0.00000	0.00000	.08290	0.00000
23	-.07843	.18651	.22247	.83837	0.00000	0.00000	0.00000	.08347	0.00000
24	-.03105	.18903	.22547	.83837	0.00000	0.00000	0.00000	.08460	0.00000

INDUCED DRAG, LEADING EDGE THRUST AND SUCTION COEFFICIENT CHARACTERISTICS
COMPUTED AT ONE RADIAN ANGLE OF ATTACK FROM A NEAR FIELD SOLUTION

STATION	2Y/B	L. E. SWEEP ANGLE	SECTION COEFFICIENTS CDII C/2B	CT C/2B	CS C/2B	CONTRIBUTIONS TO TOTAL COEF. FROM EACH SPANWISE ROW CDII	CT	CS
1	-.96667	24.73430	-.00038	.16725	.18414	-.00015	.06716	.07395
2	-.90000	24.73430	-.00024	.23627	.26014	-.00010	.09488	.10446
3	-.83333	24.73430	.00054	.28149	.30992	.00022	.11304	.12446
4	-.76667	24.73430	.00192	.31625	.34820	.00077	.12700	.13983
5	-.70000	24.73430	.00355	.34561	.38052	.00143	.13879	.15281
6	-.63333	24.73430	.00474	.37232	.40992	.00190	.14951	.16462
7	-.56667	24.73430	.00407	.39877	.43905	.00163	.16014	.17631
8	-.50359	24.73430	-.00350	.42974	.47314	-.00125	.15396	.16951
9	-.44608	24.73430	-.01073	.45849	.50480	-.00359	.15343	.16893
10	-.38497	63.69569	-.03036	.50372	1.13671	-.01219	.20228	.45647
11	-.31830	63.69569	.12328	.37670	.85008	.04950	.15127	.34137
12	-.25163	63.69569	.20760	.31529	.71150	.08337	.12661	.28572
13	-.19575	63.69569	.46763	.07159	.16156	.12703	.01945	.04389
14	-.13399	79.48296	.33782	.21617	1.18431	.15960	.10213	.55951
15	-.07843	82.09284	.35632	.20428	1.48494	.07014	.04021	0.00000
16	-.03105	79.74318	.47681	.08704	.48885	.17834	.03256	.18284
			CONTRIBUTION OF THE SECOND PLANFORM TO THE CHORD OR DRAG FORCE					
17	-.44608	54.99910	.02642	.03560	.C62C7	.00884	.01191	.02077
18	-.38497	54.99910	.04696	.03336	.C5816	.01886	.01340	.02336
19	-.31830	54.99910	.05942	.02607	.C4545	.02386	.01047	.01825
20	-.25163	54.99910	.06628	.01995	.C3479	.02662	.00801	.01397
21	-.19575	54.99910	.06997	.01549	.C2701	.01901	.00421	.00734
22	-.13399	0.00000	.08342	.00030	.C0030	.03941	.00014	.00014
23	-.07843	0.00000	.08328	.00101	.C0101	.01639	.00020	.00020
24	-.03105	0.00000	.08384	.00159	.CC159	.03136	.00059	.00059

TOTAL COEFFICIENTS

CDII/CL**2 = .05674 CT= 3.76272 CS= 6.45859

THIS CASE IS FINISHED

CONFIGURATION NO. 113

CURVE 5 IS SWEPT 24.73400 DEGREES ON PLANFORM 1

CURVE 1 IS SWEPT 0.00000 DEGREES ON PLANFCRM 2

BREAK POINTS FOR THIS CONFIGURATICN

POINT	X	Y	Z	SWEEP ANGLE	CIHEDRAL ANGLE	MOVE CODE
1	48.30000	0.00000	0.00000	79.74318	0.00000	1
2	37.80000	-1.90000	0.00000	82.09284	0.00000	1
3	30.60000	-2.90000	0.00000	79.48296	0.00000	1
4	17.67222	-5.30000	0.00000	63.69569	0.00000	1
5	2.50000	-12.80000	0.00000	24.73430	0.00000	2
6	1.71685	-14.50000	0.00000	24.73430	0.00000	2
7	-5.70000	-30.60000	0.00000	90.00000	0.00000	2
8	-11.00000	-30.60000	0.00000	8.93957	0.00000	2
9	-8.20000	-12.80000	0.00000	-17.04903	0.00000	1
10	-10.50000	-5.30000	0.00000	0.00000	0.00000	1
11	-10.50000	0.00000	0.00000			

SECOND PLANFORM BREAK POINTS

POINT	X	Y	Z	SWEEP ANGLE	CIHEDRAL ANGLE	MOVE CODE
1	-10.50000	0.00000	0.00000	0.00000	0.00000	1
2	-10.50000	-1.90000	0.00000	0.00000	0.00000	1
3	-10.50000	-2.90000	0.00000	0.00000	0.00000	1
4	-10.50000	-5.30000	0.00000	90.00000	0.00000	1
5	-17.35000	-5.30000	0.00000	54.99910	0.00000	1
6	-28.06075	-12.80000	0.00000	54.99910	0.00000	1
7	-30.48852	-14.50000	0.00000	90.00000	0.00000	1
8	-34.84463	-14.50000	0.00000	29.99999	0.00000	1
9	-29.53301	-5.30000	0.00000	0.00000	0.00000	1
10	-29.53301	0.00000	0.00000			

89 HORSESHOE VORTICES USED ON THE LEFT HALF OF THE CONFIGURATION

PLANFORM	TOTAL	SPANWISE
1	65	16
2	24	8

TABLE OF HORSESHOE VORTICES IN EACH CHORDWISE ROW (FROM TIP TO ROOT BEGINNING WITH FIRST PLANFORM)

3	3	3	3	3	3	3	3	3	4	4	4	4	6	8	8	3	3	3	3	3	3	3	3

AERODYNAMIC DATA

CONFIGURATION NO. 113

STATIC LONGITUDINAL AERODYNAMIC COEFFICIENTS ARE COMPUTED

X C/4	X 3C/4	Y	Z	S	C/4 SWEEP ANGLE	DIHEDRAL ANGLE	LOCAL ALPHA IN RADIANS	DELTA CP AT DESIRED CL = 1.00000
-5.69757	-6.63247	-29.58000	0.00000	1.02000	23.52798	0.00000	0.00000	1.62054
-7.56738	-8.50228	-29.58000	0.00000	1.02000	18.48322	0.00000	0.00000	.45244
-9.43719	-10.37210	-29.58000	0.00000	1.02000	13.12385	0.00000	0.00000	.18335
-4.80936	-5.84742	-27.54000	0.00000	1.02000	23.52798	0.00000	0.00000	1.92478
-6.88547	-7.92352	-27.54000	0.00000	1.02000	18.48322	0.00000	0.00000	.66122
-8.96157	-9.99963	-27.54000	0.00000	1.02000	13.12385	0.00000	0.00000	.28672
-3.92116	-5.06236	-25.50000	0.00000	1.02000	23.52798	0.00000	0.00000	2.03034
-6.20356	-7.34476	-25.50000	0.00000	1.02000	18.48322	0.00000	0.00000	.74789
-8.48596	-9.62715	-25.50000	0.00000	1.02000	13.12385	0.00000	0.00000	.34219
-3.03296	-4.27730	-23.46000	0.00000	1.02000	23.52798	0.00000	0.00000	2.07084
-5.52165	-6.76599	-23.46000	0.00000	1.02000	18.48322	0.00000	0.00000	.78561
-8.01034	-9.25468	-23.46000	0.00000	1.02000	13.12385	0.00000	0.00000	.36994
-2.14476	-3.49225	-21.42000	0.00000	1.02000	23.52798	0.00000	0.00000	2.08358
-4.83974	-6.18723	-21.42000	0.00000	1.02000	18.48322	0.00000	0.00000	.80093
-7.53472	-8.88221	-21.42000	0.00000	1.02000	13.12385	0.00000	0.00000	.38289
-1.25655	-2.70719	-19.38000	0.00000	1.02000	23.52798	0.00000	0.00000	2.08351
-4.15783	-5.60846	-19.38000	0.00000	1.02000	18.48322	0.00000	0.00000	.80424
-7.05910	-8.50974	-19.38000	0.00000	1.02000	13.12385	0.00000	0.00000	.38756
-.36835	-1.92213	-17.34000	0.00000	1.02000	23.52798	0.00000	0.00000	2.07787
-3.47592	-5.02970	-17.34000	0.00000	1.02000	18.48322	0.00000	0.00000	.79947
-6.58348	-8.13727	-17.34000	0.00000	1.02000	13.12385	0.00000	0.00000	.38733
.47196	-1.17941	-15.41000	0.00000	.91000	23.52798	0.00000	0.00000	2.07269
-2.83078	-4.48214	-15.41000	0.00000	.91000	18.48322	0.00000	0.00000	.78972
-6.13351	-7.78488	-15.41000	0.00000	.91000	13.12385	0.00000	0.00000	.38549
1.23825	-.50211	-13.65000	0.00000	.85000	23.52798	0.00000	0.00000	2.06276
-2.24246	-3.98282	-13.65000	0.00000	.85000	18.48322	0.00000	0.00000	.78686
-5.72317	-7.46353	-13.65000	0.00000	.85000	13.12385	0.00000	0.00000	.38557
3.74616	2.11163	-11.78000	0.00000	1.02000	61.95744	0.00000	0.00000	1.67914
.47710	-1.15743	-11.78000	0.00000	1.02000	52.32366	0.00000	0.00000	1.00746
-2.79195	-4.42648	-11.78000	0.00000	1.02000	35.47163	0.00000	0.00000	.61348
-6.06101	-7.69554	-11.78000	0.00000	1.02000	7.41473	0.00000	0.00000	.33805
7.57597	5.34739	-9.74000	0.00000	1.02000	61.95744	0.00000	0.00000	1.23378
3.11881	.89022	-9.74000	0.00000	1.02000	52.32366	0.00000	0.00000	.73321

-1.33836	-3.56694	-9.74000	0.00000	1.02000	35.47163	0.00000	0.00000	.54376
-5.79553	-8.02411	-9.74000	0.00000	1.02000	7.41473	0.00000	0.00000	.30420
11.40579	8.58315	-7.70000	0.00000	1.02000	61.95744	0.00000	0.00000	.99167
5.76051	2.93787	-7.70000	0.00000	1.02000	52.32366	0.00000	0.00000	.57974
.11524	-2.70740	-7.70000	0.00000	1.02000	35.47163	0.00000	0.00000	.46974
-5.53004	-8.35268	-7.70000	0.00000	1.02000	7.41473	0.00000	0.00000	.28006
14.61608	11.29548	-5.99000	0.00000	.69000	61.95744	0.00000	0.00000	.84840
7.97488	4.65429	-5.99000	0.00000	.69000	52.32366	0.00000	0.00000	.48091
1.33369	-1.98691	-5.99000	0.00000	.69000	35.47163	0.00000	0.00000	.42915
-5.30750	-8.62810	-5.99000	0.00000	.69000	7.41473	0.00000	0.00000	.27372
22.69294	19.80660	-4.10000	0.00000	1.20000	79.03655	0.00000	0.00000	.54416
16.92025	14.03391	-4.10000	0.00000	1.20000	76.80254	0.00000	0.00000	.42989
11.14757	8.26123	-4.10000	0.00000	1.20000	73.45675	0.00000	0.00000	.41896
5.37488	2.48854	-4.10000	0.00000	1.20000	67.94972	0.00000	0.00000	.39720
-.39780	-3.28414	-4.10000	0.00000	1.20000	57.52312	0.00000	0.00000	.36421
-6.17049	-9.05683	-4.10000	0.00000	1.20000	33.95325	0.00000	0.00000	.24425
32.80312	30.00937	-2.40000	0.00000	.50000	81.84115	0.00000	0.00000	.33719
27.21562	24.42187	-2.40000	0.00000	.50000	80.65242	0.00000	0.00000	.28671
21.62812	18.83437	-2.40000	0.00000	.50000	79.06315	0.00000	0.00000	.30541
16.04062	13.24687	-2.40000	0.00000	.50000	76.83421	0.00000	0.00000	.33849
10.45312	7.65937	-2.40000	0.00000	.50000	73.49564	0.00000	0.00000	.33710
4.86563	2.07188	-2.40000	0.00000	.50000	67.99930	0.00000	0.00000	.31611
-.72187	-3.51562	-2.40000	0.00000	.50000	57.58769	0.00000	0.00000	.34084
-6.30937	-9.10312	-2.40000	0.00000	.50000	34.01935	0.00000	0.00000	.24436
41.37656	38.02969	-.95000	0.00000	.95000	79.41967	0.00000	0.00000	.25520
34.68281	31.33594	-.95000	0.00000	.95000	77.89558	0.00000	0.00000	.16232
27.98906	24.64219	-.95000	0.00000	.95000	75.86890	0.00000	0.00000	.19914
21.29531	17.94844	-.95000	0.00000	.95000	73.05078	0.00000	0.00000	.26441
14.60156	11.25469	-.95000	0.00000	.95000	68.89183	0.00000	0.00000	.33059
7.90781	4.56094	-.95000	0.00000	.95000	62.23737	0.00000	0.00000	.34434
1.21406	-2.13281	-.95000	0.00000	.95000	50.40208	0.00000	0.00000	.32236
-5.47969	-8.82656	-.95000	0.00000	.95000	27.38832	0.00000	0.00000	.22541

SECOND PLANFORM HORSESHOE VORTEX DESCRIPTIONS

-29.69791	-30.54445	-13.65000	0.00000	.85000	53.61688	0.00000	-.17453	-.29770
-31.39099	-32.23753	-13.65000	0.00000	.85000	47.03335	0.00000	-.17453	-.08750
-33.08407	-33.93061	-13.65000	0.00000	.85000	38.31006	0.00000	-.17453	-.02809
-27.15993	-28.27163	-11.78000	0.00000	1.02000	53.61688	0.00000	-.17453	-.31877
-29.38332	-30.49501	-11.78000	0.00000	1.02000	47.03335	0.00000	-.17453	-.11453
-31.60670	-32.71839	-11.78000	0.00000	1.02000	38.31006	0.00000	-.17453	-.04632
-24.39124	-25.79218	-9.74000	0.00000	1.02000	53.61688	0.00000	-.17453	-.29927
-27.19313	-28.59408	-9.74000	0.00000	1.02000	47.03335	0.00000	-.17453	-.10659
-29.99502	-31.39597	-9.74000	0.00000	1.02000	38.31006	0.00000	-.17453	-.04683
-21.62254	-23.31274	-7.70000	0.00000	1.02000	53.61688	0.00000	-.17453	-.23532
-25.00294	-26.69315	-7.70000	0.00000	1.02000	47.03335	0.00000	-.17453	-.08528
-28.38335	-30.07355	-7.70000	0.00000	1.02000	38.31006	0.00000	-.17453	-.03904
-19.30172	-21.23439	-5.99000	0.00000	.69000	53.61688	0.00000	-.17453	-.12000
-23.16705	-25.09972	-5.99000	0.00000	.69000	47.03335	0.00000	-.17453	-.05594
-27.03238	-28.96505	-5.99000	0.00000	.69000	38.31006	0.00000	-.17453	-.02752
-12.08608	-15.25825	-4.10000	0.00000	1.20000	0.00000	0.00000	0.00000	.07490

-18.43042	-21.60259	-4.10000	0.00000	1.20000	0.00000	0.00000	0.00000	-.00193
-24.77476	-27.94693	-4.10000	0.00000	1.20000	0.00000	0.00000	0.00000	-.01962
-12.08608	-15.25825	-2.40000	0.00000	.50000	0.00000	0.00000	0.00000	.08923
-18.43042	-21.60259	-2.40000	0.00000	.50000	0.0C000	0.00000	0.00000	.01351
-24.77476	-27.94693	-2.40000	0.00000	.50000	0.0CC00	0.00000	0.00000	-.01000
-12.08608	-15.25825	-.95000	0.00000	.95000	0.0C000	0.00000	0.00000	.09966
-18.43042	-21.60259	-.95000	0.00000	.95000	0.00000	0.00000	0.00000	.02208
-24.77476	-27.94693	-.95000	0.00000	.95000	0.0C000	0.00000	0.00000	-.00443

REF. CHORD	C AVERAGE	TRUE AREA	REFERENCE AREA	B/2	REF. AR	TRUE AR	MACH NJMBER
1C.95000	22.70253	1389.39479	621.79200	30.60000	6.02362	2.69573	0.00000

COMPLETE CONFIGURATION

DESIRED CL	COMPUTED ALPHA
1.00000	11.99022

WING-BODY CHARACTERISTICS

LIFT	INDUCED DRAG (FAR FIELD SOLUTION)	
CL(WB)	CDI AT CL(WB)	CDI/(CL(WB)**2) (1/(PI*AR) = .05284)
1.02156	.05567	.05334

COMPLETE CONFIGURATION CHARACTERISTICS

CL ALPHA PER RADIAN	CL ALPHA PER DEGREE	CL(TWIST)	ALPHA AT CL=0	Y CP	CM/CL	CMO
5.44470	.09503	-.13941	1.46701	-.40193	.05780	.27393

ADDITIONAL LOADING
WITH CL BASED ON S(TRUE)

STATION	2Y/B	SL COEF	CL RATIO	C RATIO	LOAD DUE TO TWIST	ADD. LOAD AT CL= -.13941	BASIC LOAD AT CL=0	SPAN LOAD AT DESIRED CL	SL COEF FROM CHORD BD VOR
1	-.96667	.36923	1.49433	.24708	-.00244	-.02304	.02060	.18583	0.00000
2	-.90000	.52225	1.90362	.27434	-.00360	-.03258	.02899	.26271	0.00000
3	-.83333	.62403	2.06904	.30160	-.00449	-.C3893	.03444	.31371	0.00000
4	-.76667	.70400	2.14071	.32887	-.00530	-.04392	.03862	.35368	0.00000
5	-.70000	.77257	2.16939	.35613	-.00608	-.C4820	.04212	.38787	0.00000
6	-.63333	.83430	2.17614	.38339	-.00686	-.C5205	.04520	.41857	0.00000
7	-.56667	.89134	2.17059	.41065	-.00764	-.05561	.04797	.44687	0.00000
8	-.50359	.94311	2.16093	.43644	-.00841	-.C5884	.05043	.47250	0.00000
9	-.44608	.99073	2.15397	.45995	-.00917	-.C6181	.05264	.49601	0.00000
10	-.38497	1.04737	1.81842	.57598	-.01020	-.C6534	.05515	.52387	0.00000
11	-.31830	1.10628	1.40871	.78532	-.01145	-.C6902	.05756	.55266	0.00000
12	-.25163	1.15697	1.16319	.99465	-.01276	-.C7218	.05942	.57720	0.00000
13	-.19575	1.19311	1.01965	1.17012	-.01391	-.C7444	.06053	.59448	0.00000
14	-.13399	1.22580	.80346	1.52565	-.01513	-.C7648	.06135	.60992	0.00000
15	-.07843	1.24042	.62999	1.96894	-.01569	-.07739	.06170	.61682	0.00000
16	-.03105	1.24762	.52893	2.35877	-.01589	-.C7784	.06194	.62029	0.00000

CONTRIBUTION OF THE SECOND PLANFORM TO SPAN LOAD DISTRIBUTION

STATION	2Y/B	SL COEF	CL RATIO	C RATIO	LOAD DUE TO TWIST	ADD. LOAD AT CL= -.13941	BASIC LOAD AT CL=0	SPAN LOAD AT DESIRED CL	SL COEF FROM CHORD BD VOR
17	-.44608	.13723	.61338	.22373	-.10080	-.00856	-.09224	-.03082	0.00000
18	-.38497	.17772	.60488	.29381	-.13759	-.01109	-.12651	-.04697	0.00000
19	-.31830	.18915	.51087	.37025	-.15232	-.C1180	-.14052	-.05587	0.00000
20	-.25163	.19080	.42713	.44670	-.15084	-.01190	-.13894	-.05355	0.00000
21	-.19575	.18909	.37020	.51078	-.13106	-.01180	-.11926	-.03464	0.00000
22	-.13399	.18525	.22097	.83837	-.07956	-.01156	-.06800	.01491	0.00000
23	-.07843	.18651	.22247	.83837	-.06919	-.01164	-.05755	.02592	0.00000
24	-.03105	.18903	.22547	.83837	-.06361	-.C1179	-.05182	.03278	0.00000

INDUCED DRAG, LEADING EDGE THRUST AND SUCTION COEFFICIENT CHARACTERISTICS
COMPUTED AT ONE RADIAN ANGLE OF ATTACK FROM A NEAR FIELD SOLUTION

			SECTION COEFFICIENTS			CONTRIBUTIONS TO TOTAL COEF. FROM EACH SPANWISE ROW		
STATION	2Y/B	L. E. SWEEP ANGLE	CDII C/2B	CT C/2B	CS C/2B	CDII	CT	CS
1	-.96667	24.73430	-.00038	.16725	.18414	-.00015	.06716	.07395
2	-.90000	24.73430	-.00024	.23627	.26014	-.00010	.09488	.10446
3	-.83333	24.73430	.00054	.28149	.3C992	.00022	.11304	.12446
4	-.76667	24.73430	.00192	.31625	.34820	.00077	.12700	.13983
5	-.70000	24.73430	.00355	.34561	.38052	.00143	.13879	.15281
6	-.63333	24.73430	.00474	.37232	.40992	.00190	.14951	.16462
7	-.56667	24.73430	.00407	.39877	.43905	.00163	.16014	.17631
8	-.50359	24.73430	-.00350	.42974	.47314	-.00125	.15396	.16951
9	-.44608	24.73430	-.01073	.45849	.50480	-.00359	.15343	.16893
10	-.38497	63.69569	-.03036	.50372	1.13671	-.01219	.20228	.45647
11	-.31830	63.69569	.12328	.37670	.85008	.04950	.15127	.34137
12	-.25163	63.69569	.20760	.31529	.71150	.08337	.12661	.28572
13	-.19575	63.69569	.46763	.07159	.16156	.12703	.01945	.04389
14	-.13399	79.48296	.33782	.21617	1.18431	.15960	.10213	.55951
15	-.07843	82.09284	.35632	.20428	1.48494	.07014	.04021	0.00000
16	-.03105	79.74318	.47681	.08704	.48885	.17834	.03256	.18284

CONTRIBUTION OF THE SECOND PLANFORM TO THE CHORD OR DRAG FORCE

17	-.44608	54.99910	.02642	.03560	.C62C7	.00884	.01191	.02C77
18	-.38497	54.99910	.04696	.03336	.05816	.01886	.01340	.02336
19	-.31830	54.99910	.05942	.02607	.C4545	.02386	.01047	.01825
20	-.25163	54.99910	.06628	.01995	.C3479	.02662	.00801	.01397
21	-.19575	54.99910	.06997	.01549	.C2701	.01901	.00421	.00734
22	-.13399	0.00000	.08342	.00030	.CC030	.03941	.00014	.00014
23	-.07843	0.00000	.08328	.00101	.C0101	.01639	.00020	.00020
24	-.03105	0.00000	.08384	.00159	.CC159	.03136	.00059	.00059

TOTAL COEFFICIENTS

CDII/CL**2 = .05674 CT= 3.76272 CS= 6.45859

THIS CASE IS FINISHED

CONFIGURATION NO. 110

CURVE 5 IS SWEPT 72.00000 DEGREES ON PLANFORM 1

CURVE 1 IS SWEPT 0.00000 DEGREES ON PLANFORM 2

BREAK POINTS FOR THIS CONFIGURATION

POINT	X	Y	Z	SWEEP ANGLE	DIHEDRAL ANGLE	MOVE CODE
1	48.30000	0.00000	0.00000	79.74318	0.00000	1
2	37.80000	-1.90000	0.00000	82.09284	0.00000	1
3	30.60000	-2.90000	0.00000	79.48296	0.00000	1
4	17.67222	-5.30000	0.00000	63.69569	0.00000	1
5	1.01204	-13.53554	0.00000	72.00000	0.00000	2
6	-1.95628	-14.50000	0.00000	72.00000	0.00000	2
7	-19.02186	-20.04495	0.00000	-42.73431	0.00000	2
8	-22.61844	-16.15205	0.00000	56.20526	0.00000	2
9	-9.80256	-7.57427	0.00000	-17.04903	0.00000	1
10	-10.50000	-5.30000	0.00000	0.00000	0.00000	1
11	-10.50000	0.00000	0.00000			

SECOND PLANFORM BREAK POINTS

POINT	X	Y	Z	SWEEP ANGLE	DIHEDRAL ANGLE	MOVE CODE
1	-10.50000	0.00000	0.00000	0.00000	0.00000	1
2	-10.50000	-1.90000	0.00000	0.00000	0.00000	1
3	-10.50000	-2.90000	0.00000	0.00000	0.00000	1
4	-10.50000	-5.30000	0.00000	90.00000	0.00000	1
5	-17.35000	-5.30000	0.00000	54.99910	0.00000	1
6	-20.59788	-7.57427	0.00000	54.99910	0.00000	1
7	-29.11117	-13.53554	0.00000	54.99910	0.00000	1
8	-30.48852	-14.50000	0.00000	90.00000	0.00000	1
9	-34.84463	-14.50000	0.00000	29.99999	0.00000	1
10	-29.53301	-5.30000	0.00000	0.00000	0.00000	1
11	-29.53301	0.00000	0.00000			

52 HORSESHOE VORTICES USED ON THE LEFT HALF OF THE CONFIGURATION

PLANFORM	TOTAL	SPANWISE
1	30	15
2	22	11

APPENDIX C

2 HORSESHOE VORTICES IN EACH CHORDWISE ROW

AERODYNAMIC DATA

CONFIGURATION NO. 110

STATIC LONGITUDINAL AERODYNAMIC COEFFICIENTS ARE COMPUTED

X C/4	X 3C/4	Y	Z	S	C/4 SWEEP ANGLE	DIHEDRAL ANGLE	LOCAL ALPHA IN RADIANS	DELTA CP AT DESIRED CL = 1.00000
-17.29967	-17.96810	-19.37678	0.00000	.66816	68.79501	0.00000	0.00000	2.27776
-18.63653	-19.30495	-19.37678	0.00000	.66816	29.97225	0.00000	0.00000	1.49203
-13.85530	-15.86058	-18.04045	0.00000	.66816	68.79501	0.00000	0.00000	1.44393
-17.86586	-19.87114	-18.04045	0.00000	.66816	29.97225	0.00000	0.00000	.58338
-10.56054	-13.84461	-16.76217	0.00000	.61012	68.79501	0.00000	0.00000	1.13855
-17.12867	-20.41273	-16.76217	0.00000	.61012	29.97225	0.00000	0.00000	.40890
-6.60924	-10.83068	-15.32603	0.00000	.82603	70.85022	0.00000	0.00000	1.01559
-15.05213	-19.27357	-15.32603	0.00000	.82603	64.40823	0.00000	0.00000	.36947
-2.84181	-7.58119	-14.01777	0.00000	.48223	70.85022	0.00000	0.00000	.96078
-12.32058	-17.05996	-14.01777	0.00000	.48223	64.40823	0.00000	0.00000	.36816
-.14561	-5.16426	-12.86737	0.00000	.66816	62.93184	0.00000	0.00000	.96534
-10.18290	-15.20155	-12.86737	0.00000	.66816	59.42230	0.00000	0.00000	.36388
2.46939	-2.72595	-11.53104	0.00000	.66816	62.93184	0.00000	0.00000	.98736
-7.92129	-13.11662	-11.53104	0.00000	.66816	59.42230	0.00000	0.00000	.36417
5.08438	-.28764	-10.19471	0.00000	.66816	62.93184	0.00000	0.00000	.98155
-5.65967	-11.03169	-10.19471	0.00000	.66816	59.42230	0.00000	0.00000	.38132
8.30204	2.71261	-8.55041	0.00000	.97614	62.93184	0.00000	0.00000	.94965
-2.87683	-8.46627	-8.55041	0.00000	.97614	59.42230	0.00000	0.00000	.41212
11.36931	5.26166	-6.90611	0.00000	.66816	59.95582	0.00000	0.00000	.86906
-.84599	-6.95364	-6.90611	0.00000	.66816	29.55082	0.00000	0.00000	.42436
13.33855	6.56863	-5.76897	0.00000	.46897	59.99582	0.00000	0.00000	.77275
-.20130	-6.97122	-5.76897	0.00000	.46897	29.55082	0.00000	0.00000	.42634
17.29992	9.35709	-4.63184	0.00000	.66816	78.02132	0.00000	0.00000	.62052
1.41425	-6.52858	-4.63184	0.00000	.66816	63.66192	0.00000	0.00000	.42284
22.95583	13.39702	-3.43184	0.00000	.53184	78.02132	0.00000	0.00000	.45593
3.83821	-5.72060	-3.43184	0.00000	.53184	63.66192	0.00000	0.00000	.42254
28.61250	17.43750	-2.40000	0.00000	.50000	80.98068	0.00000	0.00000	.35429
6.26250	-4.91250	-2.40000	0.00000	.50000	69.67686	0.00000	0.00000	.40269
36.35625	22.96875	-.95000	0.00000	.95000	78.31579	0.00000	0.00000	.27371
9.58125	-3.80625	-.95000	0.00000	.95000	64.24085	0.00000	0.00000	.36088

SECOND PLANFORM HORSESHOE VORTEX DESCRIPTIONS

-30.39564	-31.58723	-14.01777	0.00000	.48223	52.88998	0.00000	0.00000	.40964
-32.77883	-33.97042	-14.01777	0.00000	.48223	41.87245	0.00000	0.00000	.06518
-28.87510	-30.31137	-12.86737	0.00000	.66816	52.88998	0.00000	0.00000	.48586
-31.74763	-33.18390	-12.86737	0.00000	.66816	41.87245	0.00000	0.00000	.12412
-27.10880	-28.82928	-11.53104	0.00000	.66816	52.88998	0.00000	0.00000	.48672
-30.54977	-32.27026	-11.53104	0.00000	.66816	41.87245	0.00000	0.00000	.15161
-25.34249	-27.34720	-10.19471	0.00000	.66816	52.88998	0.00000	0.00000	.47283
-29.35191	-31.35662	-10.19471	0.00000	.66816	41.87245	0.00000	0.00000	.16124
-23.16912	-25.52356	-8.55041	0.00000	.97614	52.88998	0.00000	0.00000	.44308
-27.87799	-30.23242	-8.55041	0.00000	.97614	41.87245	0.00000	0.00000	.16084
-20.99576	-23.69991	-6.90611	0.00000	.66816	52.88998	0.00000	0.00000	.38756
-26.40406	-29.10822	-6.90611	0.00000	.66816	41.87245	0.00000	0.00000	.15274
-19.49274	-22.43875	-5.76897	0.00000	.46897	52.88998	0.00000	0.00000	.34027
-25.38476	-28.33077	-5.76897	0.00000	.46897	41.87245	0.00000	0.00000	.15144
-12.87913	-17.63738	-4.63184	0.00000	.66816	0.00000	0.00000	0.00000	.10625
-22.39563	-27.15388	-4.63184	0.00000	.66816	0.00000	0.00000	0.00000	.19740
-12.87913	-17.63738	-3.43184	0.00000	.53184	0.00000	0.00000	0.00000	.14482
-22.39563	-27.15388	-3.43184	0.00000	.53184	0.00000	0.00000	0.00000	.16726
-12.87913	-17.63738	-2.40000	0.00000	.50000	0.00000	0.00000	0.00000	.16867
-22.39563	-27.15388	-2.40000	0.00000	.50000	0.00000	0.00000	0.00000	.15220
-12.87913	-17.63738	-.95000	0.00000	.95000	0.00000	0.00000	0.00000	.18824
-22.39563	-27.15388	-.95000	0.00000	.95000	0.00000	0.00000	0.00000	.14214

REF. CHORD	C AVERAGE	TRUE AREA	REFERENCE AREA	B/2	REF. AR	TRUE AR	MACH NUMBER
10.95000	33.32685	1336.06970	621.79200	20.04495	2.58479	1.20293	0.00000

COMPLETE CONFIGURATION

DESIRED CL	COMPUTED ALPHA
1.00000	17.41791

WING-BODY CHARACTERISTICS

LIFT	INDUCED DRAG (FAR FIELD SOLUTION)	
CL(WB)	CDI AT CL(WB)	CDI/(CL(WB)**2) (1/(PI*AR) = .12315)
.87781	.09470	.12290

COMPLETE CONFIGURATION CHARACTERISTICS

CL ALPHA PER RADIAN	CL ALPHA PER DEGREE	CL(TWIST)	ALPHA AT CL=0	Y CP	CM/CL	CMO
3.28948	.05741	0.00000	-0.00000	-.41958	.10342	0.00000

ADDITIONAL LOADING
WITH CL BASED ON S(TRUE)

STATION	2Y/B	SL COEF	CL RATIO	C RATIO	LOAD DUE TO TWIST	ADD. LOAD AT CL= 0.00000	BASIC LOAD AT CL=0	SPAN LOAD AT DESIRED CL	SL COEF FROM CHORD BD VOR
1	-.96667	.32493	4.05015	.08023	0.00000	0.00000	0.00000	.15122	0.00000
2	-.90000	.52422	2.17809	.24068	0.00000	0.00000	0.00000	.24397	0.00000
3	-.83623	.65531	1.66253	.39416	0.00000	0.00000	0.00000	.30497	0.00000
4	-.76458	.75396	1.48807	.50667	0.00000	0.00000	0.00000	.35089	0.00000
5	-.69932	.81218	1.42778	.56884	0.00000	0.00000	0.00000	.37798	0.00000
6	-.64193	.86021	1.42808	.60235	0.00000	0.00000	0.00000	.40033	0.00000
7	-.57526	.90544	1.45204	.62356	0.00000	0.00000	0.00000	.42138	0.00000
8	-.50859	.94409	1.46424	.64477	0.00000	0.00000	0.00000	.43937	0.00000
9	-.42656	.98151	1.46305	.67086	0.00000	0.00000	0.00000	.45678	0.00000
10	-.34453	1.01868	1.38962	.73306	0.00000	0.00000	0.00000	.47403	0.00000
11	-.28780	1.04678	1.28827	.81255	0.00000	0.00000	0.00000	.48716	0.00000
12	-.23107	1.06863	1.12095	.95333	0.00000	0.00000	0.00000	.49733	0.00000
13	-.17121	1.08282	.94381	1.14728	0.00000	0.00000	0.00000	.50393	0.00000
14	-.11973	1.09081	.81327	1.34126	0.00000	0.00000	0.00000	.50765	0.00000
15	-.04739	1.09550	.68179	1.60681	0.00000	0.00000	0.00000	.50983	0.00000

CONTRIBUTION OF THE SECOND PLANFORM TO SPAN LOAD DISTRIBUTION

STATION	2Y/B	SL COEF	CL RATIO	C RATIO	LOAD DUE TO TWIST	ADD. LOAD AT CL= 0.00000	BASIC LOAD AT CL=0	SPAN LOAD AT DESIRED CL	SL COEF FROM CHORD BD VOR
16	-.69932	.07296	.51014	.14302	0.00000	0.00000	0.00000	.03395	0.00000
17	-.64193	.11297	.65534	.17239	0.00000	0.00000	0.00000	.05258	0.00000
18	-.57526	.14162	.68581	.20650	0.00000	0.00000	0.00000	.06591	0.00000
19	-.50859	.16391	.68122	.24061	0.00000	0.00000	0.00000	.07628	0.00000
20	-.42656	.18335	.64883	.28259	0.00000	0.00000	0.00000	.08533	0.00000
21	-.34453	.18840	.58048	.32456	0.00000	0.00000	0.00000	.08769	0.00000
22	-.28780	.18679	.52827	.35359	0.00000	0.00000	0.00000	.08693	0.00000
23	-.23107	.18631	.32623	.57110	0.00000	0.00000	0.00000	.08671	0.00000
24	-.17121	.19148	.33529	.57110	0.00000	0.00000	0.00000	.08911	0.00000
25	-.11973	.19688	.34473	.57110	0.00000	0.00000	0.00000	.09162	0.00000
26	-.04739	.20272	.35495	.57110	0.00000	0.00000	0.00000	.09434	0.00000

INDUCED DRAG, LEADING EDGE THRUST AND SUCTION COEFFICIENT CHARACTERISTICS
COMPUTED AT ONE RADIAN ANGLE OF ATTACK FROM A NEAR FIELD SOLUTION

			SECTION COEFFICIENTS			CONTRIBUTIONS TO TOTAL COEF. FROM EACH SPANWISE ROW		
STATION	2Y/B	L. E. SWEEP ANGLE	CDII C/2B	CT C/2B	CS C/2B	CDII	CT	CS
1	-.96667	72.00000	-.20409	.41085	1.32954	-.03517	.07080	.22911
2	-.90000	72.00000	-.19363	.52720	1.70606	-.03337	.09085	.29399
3	-.83623	72.00000	-.16909	.58607	1.89657	-.02661	.09222	.29842
4	-.76458	72.00000	-.06342	.54318	1.75777	-.01351	.11571	.37446
5	-.69932	72.00000	-.07444	.59124	1.91330	-.00926	.07353	.23795
6	-.64193	63.69569	.01166	.53570	1.20888	.00201	.09231	.20831
7	-.57526	63.69569	.07106	.50508	1.13979	.01224	.08704	.19641
8	-.50859	63.69569	.12248	.47826	1.07925	.02111	.08241	.18598
9	-.42656	63.69569	.18286	.44168	.99672	.04604	.11119	.25092
10	-.34453	63.69569	.28674	.36146	.81568	.04941	.06229	.14056
11	-.28780	63.69569	.23796	.42812	.96610	.02878	.05178	.11685
12	-.23107	79.48296	.37450	.30548	1.67361	.06453	.05264	.28839
13	-.17121	79.48296	.29412	.39489	2.16347	.04034	.05416	.29674
14	-.11973	82.09284	.34318	.35092	2.55088	.04425	.04525	0.00000
15	-.04739	79.74318	.84882	-.15174	-.85216	.20796	-.03718	-.20878

CONTRIBUTION OF THE SECOND PLANFORM TO THE CHORD OR DRAG FORCE

16	-.69932	54.99910	.02649	.01994	.03476	.00329	.00248	.00432
17	-.64193	54.99910	.04684	.02505	.04367	.00807	.00432	.00753
18	-.57526	54.99910	.06096	.02915	.05082	.01051	.00502	.00876
19	-.50859	54.99910	.07262	.03167	.05522	.01251	.00546	.00952
20	-.42656	54.99910	.08603	.03063	.05341	.02166	.00771	.01345
21	-.34453	54.99910	.09920	.02068	.03606	.01709	.00356	.00621
22	-.28780	54.99910	.12579	-.00693	-.01209	.01521	-.00084	-.00146
23	-.23107	0.00000	.10693	.01163	.01163	.01843	.00200	.00200
24	-.17121	0.00000	.11739	.00446	.00446	.01610	.00061	.00061
25	-.11973	0.00000	.12023	.00504	.00504	.01550	.00065	.00065
26	-.04739	0.00000	.12225	.00674	.00674	.02995	.00165	.00165

TOTAL COEFFICIENTS

CDII/CL**2 = .10482 CT= 2.15527 CS= 5.92506

THIS CASE IS FINISHED

GEOMETRY DATA

REFERENCE PLANFORM HAS 14 CURVES

ROOT CHORD HEIGHT = 0.00000 VARIABLE SWEEP PIVOT POSITION X(S) = 0.00000 Y(S) = 0.00000

BREAK POINTS FOR THE REFERENCE PLANFORM

POINT	X REF	Y REF	SWEEP ANGLE	DIHEDRAL ANGLE	MOVE CODE
1	33.32500	0.00000	82.51413	C.C0000	1
2	25.90500	-.97500	90.00000	0.00000	1
3	18.10500	-.97500	73.96679	C.00000	1
4	-6.44500	-8.03000	68.42604	C.CC000	1
5	-10.79500	-9.75000	64.91246	C.00000	1
6	-14.34500	-11.41200	90.00000	C.C0000	1
7	-15.72500	-11.41200	30.52577	C.00000	1
8	-14.74500	-9.75000	32.36329	C.CC000	1
9	-13.65500	-8.03000	35.58737	C.00000	1
10	-12.09500	-5.85000	32.41231	0.00000	1
11	-11.09500	-4.27500	18.97041	C.CC000	1
12	-10.54500	-2.67500	3.36646	C.00000	1
13	-10.44500	-.97500	90.00000	C.00000	1
14	-12.42500	-.97500	0.00000	C.C0000	1
15	-12.42500	0.00000			

CONFIGURATION NO. 15

CURVE 1 IS SWEPT 82.51413 DEGREES ON PLANFORM 1

BREAK POINTS FOR THIS CONFIGURATICN

POINT	X	Y	Z	SWEEP ANGLE	DIHEDRAL ANGLE	MOVE CODE
1	33.32500	0.00000	0.00000	82.51413	0.00000	1
2	25.90500	-.97500	0.00000	90.00000	0.00000	1
3	18.10500	-.97500	0.00000	73.96679	0.00000	1
4	-6.44500	-8.03000	0.00000	68.42604	0.00000	1
5	-10.79500	-9.75000	0.00000	64.91246	0.00000	1
6	-14.34500	-11.41200	0.00000	90.00000	0.00000	1
7	-15.72500	-11.41200	0.00000	30.52577	0.00000	1
8	-14.74500	-9.75000	0.00000	32.36329	0.00000	1
9	-13.65500	-8.03000	0.00000	35.58737	0.00000	1
10	-12.09500	-5.85000	0.00000	32.41231	0.00000	1
11	-11.09500	-4.27500	0.00000	18.97041	0.00000	1
12	-10.54500	-2.67500	0.00000	3.36646	0.00000	1
13	-10.44500	-.97500	0.00000	90.00000	0.00000	1
14	-12.42500	-.97500	0.00000	0.00000	0.00000	1
15	-12.42500	0.00000	0.00000			

61 HORSESHOE VORTICES USED ON THE LEFT HALF OF THE CONFIGURATION

PLANFORM	TOTAL	SPANWISE
1	61	7

TABLE OF HORSESHOE VORTICES IN EACH CHORDWISE ROW (FROM TIP TO ROOT BEGINNING WITH FIRST PLANFORM)

4 8 9 9 9 9 13

AERODYNAMIC DATA

CONFIGURATION NO. 15

STATIC LONGITUDINAL AERODYNAMIC COEFFICIENTS ARE COMPUTED

X C/4	X 3C/4	Y	Z	S	C/4 SWEEP ANGLE	DIHEDRAL ANGLE	LOCAL ALPHA IN RADIANS	DELTA CP AT DESIRED CL = 1.00000
-12.73656	-13.06969	-10.58100	0.00000	.83100	67.57331	0.00000	.13960	5.55675
-13.40281	-13.73594	-10.58100	0.00000	.83100	63.01251	0.00000	.14600	2.80004
-14.06906	-14.40219	-10.58100	0.00000	.83100	56.38671	0.00000	.17050	1.97062
-14.73531	-15.06844	-10.58100	0.00000	.83100	46.26214	0.00000	.18970	1.20569
-8.79437	-9.14312	-8.89000	0.00000	.86000	71.18206	0.00000	.08470	5.26525
-9.49187	-9.84062	-8.89000	0.00000	.86000	69.34685	0.00000	.07600	2.70239
-10.18937	-10.53812	-8.89000	0.00000	.86000	67.13605	0.00000	.09750	2.10287
-10.88687	-11.23562	-8.89000	0.00000	.86000	64.43039	0.00000	.13260	1.77584
-11.58437	-11.93312	-8.89000	0.00000	.86000	61.06008	0.00000	.13390	1.46133
-12.28187	-12.63062	-8.89000	0.00000	.86000	56.78056	0.00000	.13430	1.20101
-12.97937	-13.32812	-8.89000	0.00000	.86000	51.24028	0.00000	.13430	.93628
-13.67687	-14.02562	-8.89000	0.00000	.86000	43.95147	0.00000	.13430	.61412
-2.93599	-3.50393	-6.94000	0.00000	1.09000	76.10788	0.00000	-.03050	3.28181
-4.07188	-4.63982	-6.94000	0.00000	1.09000	74.79083	0.00000	.01900	1.80268
-5.20776	-5.77571	-6.94000	0.00000	1.09000	73.20581	0.00000	.05050	1.44576
-6.34365	-6.91159	-6.94000	0.00000	1.09000	71.26512	0.00000	.06650	1.26496
-7.47954	-8.04748	-6.94000	0.00000	1.09000	68.84035	0.00000	.08300	1.15024
-8.61542	-9.18337	-6.94000	0.00000	1.09000	65.73761	0.00000	.09600	1.03857
-9.75131	-10.31925	-6.94000	0.00000	1.09000	61.65515	0.00000	.09800	.90695
-10.88720	-11.45514	-6.94000	0.00000	1.09000	56.11167	0.00000	.11600	.77494
-12.02308	-12.59103	-6.94000	0.00000	1.09000	48.33861	0.00000	.11900	.52004
3.45141	2.59162	-5.06250	0.00000	.78750	76.09908	0.00000	-.03050	2.42030
1.73182	.87203	-5.06250	0.00000	.78750	74.73816	0.00000	.01370	1.34626
.01223	-.84756	-5.06250	0.00000	.78750	73.09042	0.00000	.04700	1.07497
-1.70736	-2.56715	-5.06250	0.00000	.78750	71.05835	0.00000	.05700	.92285
-3.42695	-4.28674	-5.06250	0.00000	.78750	68.49721	0.00000	.07900	.84903
-5.14654	-6.00633	-5.06250	0.00000	.78750	65.18511	0.00000	.08400	.75999
-6.86613	-7.72592	-5.06250	0.00000	.78750	60.77093	0.00000	.08500	.67570
-8.58572	-9.44551	-5.06250	0.00000	.78750	54.68558	0.00000	.09100	.58152
-10.30531	-11.16510	-5.06250	0.00000	.78750	46.01394	0.00000	.09800	.42252
8.84368	7.72004	-3.47500	0.00000	.80000	76.06723	0.00000	-.01100	1.86509
6.59640	5.47276	-3.47500	0.00000	.80000	74.54505	0.00000	.02700	1.06827
4.34912	3.22548	-3.47500	0.00000	.80000	72.66087	0.00000	.05040	.88681

2.10184	.97821	-3.47500	0.00000	.80000	70.27413	0.00000	.07250	.79990
-.14543	-1.26907	-3.47500	0.00000	.80000	67.16567	0.00000	.07100	.70873
-2.39271	-3.51635	-3.47500	0.00000	.80000	62.98003	0.00000	.09200	.67688
-4.63999	-5.76363	-3.47500	0.00000	.80000	57.11951	0.00000	.10100	.59743
-6.88726	-8.01090	-3.47500	0.00000	.80000	48.56593	0.00000	.09800	.49173
-9.13454	-10.25818	-3.47500	0.00000	.80000	35.71302	0.00000	.07550	.32295
14.43489	13.01032	-1.82500	0.00000	.85000	76.03593	0.00000	.01180	1.36665
11.58576	10.16119	-1.82500	0.00000	.85000	74.35141	0.00000	.06160	.83563
8.73663	7.31206	-1.82500	0.00000	.85000	72.21956	0.00000	.07000	.70910
5.88750	4.46293	-1.82500	0.00000	.85000	69.44403	0.00000	.08320	.67644
3.03837	1.61380	-1.82500	0.00000	.85000	65.70298	0.00000	.09800	.65747
.18924	-1.23533	-1.82500	0.00000	.85000	60.44367	0.00000	.09360	.59153
-2.65989	-4.08446	-1.82500	0.00000	.85000	52.68197	0.00000	.08300	.52627
-5.50902	-6.93359	-1.82500	0.00000	.85000	40.70264	0.00000	.06840	.43161
-8.35815	-9.78272	-1.82500	0.00000	.85000	22.22497	0.00000	.05340	.29207
28.80654	27.18962	-.48750	0.00000	.48750	83.56624	0.00000	0.00000	.44567
25.57269	23.95577	-.48750	0.00000	.48750	83.02387	0.00000	0.00000	.20828
22.33885	20.72192	-.48750	0.00000	.48750	82.38223	0.00000	.04700	.17615
19.10500	17.48808	-.48750	0.00000	.48750	81.61153	0.00000	.10300	.26631
15.87115	14.25423	-.48750	0.00000	.48750	80.66887	0.00000	.10300	.53043
12.63731	11.02038	-.48750	0.00000	.48750	79.49019	0.00000	.10300	.59118
9.40346	7.78654	-.48750	0.00000	.48750	77.97569	0.00000	.10300	.59719
6.16962	4.55269	-.48750	0.00000	.48750	75.96141	0.00000	.10300	.60619
2.93577	1.31885	-.48750	0.00000	.48750	73.15977	0.00000	.10300	.59360
-.29808	-1.91500	-.48750	0.00000	.48750	69.02318	0.00000	.08700	.52567
-3.53192	-5.14885	-.48750	0.00000	.48750	62.39862	0.00000	.08700	.47605
-6.76577	-8.38269	-.48750	0.00000	.48750	50.59446	0.00000	.08700	.36321
-9.99962	-11.61654	-.48750	0.00000	.48750	27.54873	0.00000	.08700	.15758

REF. CHORD	C AVERAGE	TRUE AREA	REFERENCE AREA	B/2	REF. AR	TRUE AR	MACH NUMBER
19.15500	15.56516	355.25921	320.68800	11.41200	1.62443	1.46635	.54000

COMPLETE CONFIGURATION

CL	COMPUTED ALPHA
-.10000	-8.42701
.10000	-2.05654
.20000	1.12870
.30000	4.31393
.40000	7.49917
.50000	10.68441
.60000	13.86964
.70000	17.05488
.80000	20.24011
.90000	23.42535
1.00000	26.61059

WING-BODY CHARACTERISTICS

LIFT CL(WB)	INDUCED DRAG (FAR FIELD SOLUTION) CDI AT CL(WB)	CDI/(CL(WB)**2) (1/(PI*AR) = .19595)
-.10000	.00230	.23021
.10000	.00224	.22412
.20000	.00800	.19995
.30000	.01761	.19570
.40000	.03109	.19428
.50000	.04842	.19367
.60000	.06961	.19335
.70000	.09465	.19317
.80000	.12356	.19306
.90000	.15632	.19299
1.00000	.19294	.19294

COMPLETE CONFIGURATION CHARACTERISTICS

CL ALPHA PER RADIAN	CL ALPHA PER DEGREE	CL(TWIST)	ALPHA AT CL=0	Y CP	CM/CL	CMO
1.79879	.03139	.16456	-5.24177	-.42796	-.04886	-.01377

ADDITIONAL LOADING
WITH CL BASED ON S(TRUE)

STATION	2Y/B	SL COEF	CL RATIO	C RATIO	LOAD DUE TO TWIST	ADD. LOAD AT CL= .16456	BASIC LOAD AT CL=0	SPAN LOAD AT DESIRED CL	SL COEF FROM CHORD BD VOR
1	-.92718	.51290	2.99564	.17122	.10687	.07619	.03067	.49366	0.00000
2	-.77900	.77406	2.15921	.35849	.13589	.11499	.02090	.71963	0.00000
3	-.60813	.97483	1.48424	.65679	.15413	.14481	.00932	.88928	0.00000
4	-.44361	1.11361	1.12001	.99429	.16034	.16543	-.00508	1.00015	0.00000
5	-.30450	1.20656	.92854	1.29941	.16106	.17923	-.01818	1.07097	0.00000
6	-.15992	1.26534	.76808	1.64741	.15991	.18797	-.02805	1.11416	0.00000
7	-.04272	1.30004	.48134	2.70090	.17007	.19312	-.02305	1.15048	0.00000

INDUCED DRAG, LEADING EDGE THRUST AND SUCTION COEFFICIENT CHARACTERISTICS
COMPUTED AT ONE RADIAN ANGLE OF ATTACK FROM A NEAR FIELD SOLUTION

STATION	2Y/B	L. E. SWEEP ANGLE	SECTION COEFFICIENTS CDII C/2B	CT C/2B	CS C/2B	CONTRIBUTIONS TO TOTAL COEF. FROM EACH SPANWISE ROW CDII	CT	CS
1	-.92718	64.91246	-.11902	.40299	.95045	-.02816	.09534	.22485

2	-.77900	68.42604	-.04563	.47421	1.28965	-.01117	.11610	.31575
3	-.60813	73.96679	.08229	.45744	1.65623	.02554	.14195	.51394
4	-.44361	73.96679	.22542	.39115	1.41621	.05054	.08769	.31750
5	-.30450	73.96679	.36493	.30310	1.C9743	.08311	.06903	.24994
6	-.15992	73.96679	.50229	.19829	.71795	.12155	.04798	.17373
7	-.04272	82.51413	.59790	.12189	.93558	.08298	.01692	0.00000

TOTAL COEFFICIENTS

CDII/CL**2 = .20051 CT= 1.15003 CS= 3.59144

THIS CASE IS FINISHED

CONFIGURATION NO. 215

CURVE 1 IS SWEPT 82.51413 DEGREES ON PLANFORM 1

BREAK POINTS FOR THIS CONFIGURATICN

POINT	X	Y	Z	SWEEP ANGLE	DIHEDRAL ANGLE	MOVE CODE
1	33.32500	0.00000	0.00000	82.51413	0.00000	1
2	25.90500	-.97500	0.00000	90.00000	0.00000	1
3	18.10500	-.97500	0.00000	73.96679	0.00000	1
4	-6.44500	-8.03000	0.00000	68.42604	0.00000	1
5	-10.79500	-9.75000	0.00000	64.91246	0.00000	1
6	-14.34500	-11.41200	0.00000	90.00000	0.00000	1
7	-15.72500	-11.41200	0.00000	30.52577	0.00000	1
8	-14.74500	-9.75000	0.00000	32.36329	0.00000	1
9	-13.65500	-8.03000	0.00000	35.58737	0.00000	1
10	-12.09500	-5.85000	0.00000	32.41231	0.00000	1
11	-11.09500	-4.27500	0.00000	18.97041	0.00000	1
12	-10.54500	-2.67500	0.00000	3.36646	0.00000	1
13	-10.44500	-.97500	0.00000	90.00000	0.00000	1
14	-12.42500	-.97500	0.00000	0.00000	0.00000	1
15	-12.42500	0.00000	0.00000			

57 HORSESHOE VORTICES USED ON THE LEFT HALF OF THE CONFIGURATION

PLANFORM	TOTAL	SPANWISE
1	57	19

3 HORSESHOE VORTICES IN EACH CHORDWISE ROW

AERODYNAMIC DATA

CONFIGURATION NO. 215

CLP IS COMPUTED

X C/4	X 3C/4	Y	Z	S	C/4 SWEEP ANGLE	DIHEDRAL ANGLE	LOCAL ALPHA IN RADIANS	DELTA CP AT DESIRED CL = 1.00000
-13.82374	-14.13544	-11.09500	0.00000	.31700	67.24976	0.00000	0.00000	12.67080
-14.44714	-14.75884	-11.09500	0.00000	.31700	60.56653	0.00000	0.00000	4.89640
-15.07053	-15.38223	-11.09500	0.00000	.31700	49.23355	0.00000	0.00000	1.75675
-12.55123	-13.02632	-10.46100	0.00000	.31700	67.24976	0.00000	0.00000	10.50411
-13.50142	-13.97651	-10.46100	0.00000	.31700	60.56653	0.00000	0.00000	4.51684
-14.45160	-14.92670	-10.46100	0.00000	.31700	49.23355	0.00000	0.00000	2.18096
-11.51957	-12.12713	-9.94700	0.00000	.19700	67.24976	0.00000	0.00000	8.99955
-12.73469	-13.34226	-9.94700	0.00000	.19700	60.56653	0.00000	0.00000	3.96561
-13.94982	-14.55738	-9.94700	0.00000	.19700	49.23355	0.00000	0.00000	2.09611
-10.37252	-11.13099	-9.43300	0.00000	.31700	70.45694	0.00000	0.00000	7.34151
-11.88946	-12.64793	-9.43300	0.00000	.31700	64.17772	0.00000	0.00000	3.60970
-13.40640	-14.16487	-9.43300	0.00000	.31700	52.76776	0.00000	0.00000	1.99542
-8.86923	-9.82797	-8.79900	0.00000	.31700	70.45694	0.00000	0.00000	5.93564
-10.78672	-11.74547	-8.79900	0.00000	.31700	64.17772	0.00000	0.00000	2.93426
-12.70421	-13.66296	-8.79900	0.00000	.31700	52.76776	0.00000	0.00000	1.76998
-7.58171	-8.71198	-8.25600	0.00000	.22600	70.45694	0.00000	0.00000	5.02197
-9.84226	-10.97253	-8.25600	0.00000	.22600	64.17772	0.00000	0.00000	2.49930
-12.10281	-13.23308	-8.25600	0.00000	.22600	52.76776	0.00000	0.00000	1.57901
-6.01576	-7.36347	-7.71300	0.00000	.31700	75.47852	0.00000	0.00000	3.93123
-8.71118	-10.05888	-7.71300	0.00000	.31700	70.12344	0.00000	0.00000	2.21384
-11.40659	-12.75430	-7.71300	0.00000	.31700	59.10589	0.00000	0.00000	1.42972
-3.95561	-5.59540	-7.07900	0.00000	.31700	75.47852	0.00000	0.00000	3.02686
-7.23519	-8.87498	-7.07900	0.00000	.31700	70.12344	0.00000	0.00000	1.76171
-10.51478	-12.15457	-7.07900	0.00000	.31700	59.10589	0.00000	0.00000	1.25807
-1.44378	-3.43969	-6.30600	0.00000	.45600	75.47852	0.00000	0.00000	2.32750
-5.43561	-7.43152	-6.30600	0.00000	.45600	70.12344	0.00000	0.00000	1.33363
-9.42744	-11.42335	-6.30600	0.00000	.45600	59.10589	0.00000	0.00000	1.04857
1.06591	-1.29038	-5.53300	0.00000	.31700	75.44969	0.00000	0.00000	1.79397
-3.64668	-6.00298	-5.53300	0.00000	.31700	69.85550	0.00000	0.00000	1.02693
-8.35928	-10.71558	-5.53300	0.00000	.31700	57.98461	0.00000	0.00000	.85144
3.61956	.88987	-4.74550	0.00000	.47050	75.44969	0.00000	0.00000	1.36509
-1.83982	-4.56951	-4.74550	0.00000	.47050	69.85550	0.00000	0.00000	.79601
-7.29920	-10.02889	-4.74550	0.00000	.47050	57.98461	0.00000	0.00000	.68522

6.16552	3.04706	-3.95800	0.00000	.31700	75.34470	0.00000	0.00000	1.01693
-.07141	-3.18987	-3.95800	0.00000	.31700	68.82820	0.00000	0.00000	.61126
-6.30834	-9.42680	-3.95800	0.00000	.31700	53.26551	0.00000	0.00000	.53730
8.20603	4.75619	-3.32400	0.00000	.31700	75.34470	0.00000	0.00000	.77200
1.30635	-2.14349	-3.32400	0.00000	.31700	68.82820	0.00000	0.00000	.48174
-5.59333	-9.04317	-3.32400	0.00000	.31700	53.26551	0.00000	0.00000	.42805
9.76054	6.05825	-2.84100	0.00000	.16600	75.34470	0.00000	0.00000	.60880
2.35596	-1.34633	-2.84100	0.00000	.16600	68.82820	0.00000	0.00000	.38955
-5.04862	-8.75092	-2.84100	0.00000	.16600	53.26551	0.00000	0.00000	.35082
11.30754	7.33774	-2.35800	0.00000	.31700	75.24052	0.00000	0.00000	.46584
3.36794	-.60186	-2.35800	0.00000	.31700	67.72157	0.00000	0.00000	.30474
-4.57166	-8.54145	-2.35800	0.00000	.31700	47.36143	0.00000	0.00000	.28026
13.33299	9.00171	-1.72400	0.00000	.31700	75.24052	0.00000	0.00000	.31545
4.67043	.33914	-1.72400	0.00000	.31700	67.72157	0.00000	0.00000	.20676
-3.99214	-8.32342	-1.72400	0.00000	.31700	47.36143	0.00000	0.00000	.20032
15.03577	10.40060	-1.19100	0.00000	.21600	75.24052	0.00000	0.00000	.19821
5.76542	1.13024	-1.19100	0.00000	.21600	67.72157	0.00000	0.00000	.13366
-3.50494	-8.14012	-1.19100	0.00000	.21600	47.36143	0.00000	0.00000	.13852
24.92225	18.13184	-.65800	0.00000	.31700	83.12050	0.00000	0.00000	.01941
11.34143	4.55102	-.65800	0.00000	.31700	79.26452	0.00000	0.00000	.09752
-2.23939	-9.02980	-.65800	0.00000	.31700	66.13614	0.00000	0.00000	.06473
28.32308	20.91434	-.17050	0.00000	.17050	83.12050	0.00000	0.00000	.00589
13.50560	6.09685	-.17050	0.00000	.17050	79.26452	0.00000	0.00000	.02444
-1.31189	-8.72063	-.17050	0.00000	.17050	66.13614	0.00000	0.00000	.01898

REF. CHORD	C AVERAGE	TRUE AREA	REFERENCE AREA	B/2	REF. AR	TRUE AR	MACH NUMBER
19.15500	15.56516	355.25921	320.68800	11.41200	1.62443	1.46635	.54000

CLP= -.12986

THIS CASE IS FINISHED

CONFIGURATION NO. 315

CURVE 1 IS SWEPT 82.51413 DEGREES ON PLANFCRM 1

BREAK POINTS FOR THIS CONFIGURATICN

POINT	X	Y	Z	SWEEP ANGLE	CIHEDRAL ANGLE	MOVE CODE
1	33.32500	0.00000	0.00000	82.51413	0.00000	1
2	25.90500	-.97500	0.00000	90.00000	0.00000	1
3	18.10500	-.97500	0.00000	73.96679	0.00000	1
4	-6.44500	-8.03000	0.00000	68.42604	0.00000	1
5	-10.79500	-9.75000	0.00000	64.91246	0.00000	1
6	-14.34500	-11.4120C	0.00000	90.00000	0.00000	1
7	-15.72500	-11.4120C	0.00000	30.52577	0.00000	1
8	-14.74500	-9.75000	0.00000	32.36329	C.C0000	1
9	-13.65500	-8.03000	0.00000	35.58737	0.00000	1
10	-12.09500	-5.85000	0.00000	32.41231	0.00000	1
11	-11.09500	-4.27500	0.00000	18.97041	0.00000	1
12	-10.54500	-2.67500	0.00000	3.36646	0.00000	1
13	-10.44500	-.97500	0.00000	90.00000	0.00000	1
14	-12.42500	-.97500	0.00000	0.00000	0.00000	1
15	-12.42500	0.00000	0.00000			

96 HORSESHOE VORTICES USED ON THE LEFT HALF CF THE CONFIGURATION

PLANFORM	TJTAL	SPANWISE
1	96	8

12 HORSESHOE VORTICES IN EACH CHORCWISE ROW

AERODYNAMIC DATA

CONFIGURATION NO. 315

CMQ AND CLQ ARE COMPUTED

X C/4	X 3C/4	Y	Z	S	C/4 SWEEP ANGLE	DIHEDRAL ANGLE	LOCAL ALPHA IN RADIANS	DELTA CP AT DESIRED CL = 1.00000
-12.62552	-12.73656	-10.58100	0.00000	.83100	68.19486	0.00000	0.00000	10.82907
-12.84760	-12.95865	-10.58100	0.00000	.83100	66.91726	0.00000	0.00000	5.52500
-13.06969	-13.18073	-10.58100	0.00000	.83100	65.49038	0.00000	0.00000	4.20965
-13.29177	-13.40281	-10.58100	0.00000	.83100	63.88855	0.00000	0.00000	3.54313
-13.51385	-13.62490	-10.58100	0.00000	.83100	62.08052	0.00000	0.00000	3.10681
-13.73594	-13.84698	-10.58100	0.00000	.83100	60.02814	0.00000	0.00000	2.77216
-13.95802	-14.06906	-10.58100	0.00000	.83100	57.68480	0.00000	0.00000	2.48210
-14.18010	-14.29115	-10.58100	0.00000	.83100	54.99368	0.00000	0.00000	2.20482
-14.40219	-14.51323	-10.58100	0.00000	.83100	51.88610	0.00000	0.00000	1.92030
-14.62427	-14.73531	-10.58100	0.00000	.83100	48.28054	0.00000	0.00000	1.61408
-14.84635	-14.95740	-10.58100	0.00000	.83100	44.08340	0.00000	0.00000	1.26738
-15.06844	-15.17948	-10.58100	0.00000	.83100	39.19392	0.00000	0.00000	.83064
-8.73625	-8.96875	-8.89000	0.00000	.86000	71.32091	0.00000	0.00000	6.14051
-9.20125	-9.43375	-8.89000	0.00000	.86000	70.15164	0.00000	0.00000	3.28023
-9.66625	-9.89875	-8.89000	0.00000	.86000	68.83333	0.00000	0.00000	2.61405
-10.13125	-10.36375	-8.89000	0.00000	.86000	67.33726	0.00000	0.00000	2.29835
-10.59625	-10.82875	-8.89000	0.00000	.86000	65.62739	0.00000	0.00000	2.10227
-11.06125	-11.29375	-8.89000	0.00000	.86000	63.65818	0.00000	0.00000	1.95377
-11.52625	-11.75875	-8.89000	0.00000	.86000	61.37168	0.00000	0.00000	1.82093
-11.99125	-12.22375	-8.89000	0.00000	.86000	58.69389	0.00000	0.00000	1.68606
-12.45625	-12.68875	-8.89000	0.00000	.86000	55.53027	0.00000	0.00000	1.53520
-12.92125	-13.15375	-8.89000	0.00000	.86000	51.76108	0.00000	0.00000	1.35276
-13.38625	-13.61875	-8.89000	0.00000	.86000	47.23801	0.00000	0.00000	1.11513
-13.85125	-14.08375	-8.89000	0.00000	.86000	41.78656	0.00000	0.00000	.76798
-4.15431	-4.53688	-7.31675	0.00000	.71325	76.18281	0.00000	0.00000	2.79301
-4.91945	-5.30201	-7.31675	0.00000	.71325	75.22789	0.00000	0.00000	1.70860
-5.68458	-6.06714	-7.31675	0.00000	.71325	74.13480	0.00000	0.00000	1.53971
-6.44971	-6.83227	-7.31675	0.00000	.71325	72.87222	0.00000	0.00000	1.52254
-7.21484	-7.59740	-7.31675	0.00000	.71325	71.39900	0.00000	0.00000	1.54595
-7.97997	-8.36253	-7.31675	0.00000	.71325	69.66015	0.00000	0.00000	1.55811
-8.74510	-9.12766	-7.31675	0.00000	.71325	67.58099	0.00000	0.00000	1.54747
-9.51023	-9.89280	-7.31675	0.00000	.71325	65.05829	0.00000	0.00000	1.50743
-10.27536	-10.65793	-7.31675	0.00000	.71325	61.94693	0.00000	0.00000	1.43019

APPENDIX C

-11.04049	-11.42306	-7.31675	0.00000	.71325	58.04038	0.00000	0.00000	1.30355
-11.80562	-12.18819	-7.31675	0.00000	.71325	53.04390	0.00000	0.00000	1.10532
-12.57075	-12.95332	-7.31675	0.00000	.71325	46.54606	0.00000	0.00000	.78118
-.42410	-.93221	-6.22675	0.00000	.37675	76.18281	0.00000	0.00000	.97094
-1.44031	-1.94842	-6.22675	0.00000	.37675	75.22789	0.00000	0.00000	.91345
-2.45653	-2.96463	-6.22675	0.00000	.37675	74.13480	0.00000	0.00000	1.08515
-3.47274	-3.98085	-6.22675	0.00000	.37675	72.87222	0.00000	0.00000	1.20913
-4.48895	-4.99706	-6.22675	0.00000	.37675	71.35900	0.00000	0.00000	1.30365
-5.50516	-6.01327	-6.22675	0.00000	.37675	69.66015	0.00000	0.00000	1.38036
-6.52138	-7.02948	-6.22675	0.00000	.37675	67.58099	0.00000	0.00000	1.43697
-7.53759	-8.04570	-6.22675	0.00000	.37675	65.05829	0.00000	0.00000	1.46093
-8.55380	-9.06191	-6.22675	0.00000	.37675	61.94693	0.00000	0.00000	1.43482
-9.57002	-10.07812	-6.22675	0.00000	.37675	58.04038	0.00000	0.00000	1.34113
-10.58623	-11.09433	-6.22675	0.00000	.37675	53.04390	0.00000	0.00000	1.15467
-11.60244	-12.11055	-6.22675	0.00000	.37675	46.54606	0.00000	0.00000	.81547
3.55889	2.91404	-5.06250	0.00000	.78750	76.17628	0.00000	0.00000	-.06460
2.26920	1.62435	-5.06250	0.00000	.78750	75.19060	0.00000	0.00000	.35989
.97950	.33466	-5.06250	0.00000	.78750	74.05748	0.00000	0.00000	.62233
-.31019	-.95504	-5.06250	0.00000	.78750	72.74227	0.00000	0.00000	.85037
-1.59988	-2.24473	-5.06250	0.00000	.78750	71.19904	0.00000	0.00000	1.04491
-2.88957	-3.53442	-5.06250	0.00000	.78750	69.36584	0.00000	0.00000	1.20787
-4.17927	-4.82411	-5.06250	0.00000	.78750	67.15751	0.00000	0.00000	1.33221
-5.46896	-6.11381	-5.06250	0.00000	.78750	64.45491	0.00000	0.00000	1.41532
-6.75865	-7.40350	-5.06250	0.00000	.78750	61.08843	0.00000	0.00000	1.44972
-8.04835	-8.69319	-5.06250	0.00000	.78750	56.81374	0.00000	0.00000	1.41264
-9.33804	-9.98288	-5.06250	0.00000	.78750	51.27548	0.00000	0.00000	1.26540
-10.62773	-11.27258	-5.06250	0.00000	.78750	43.95786	0.00000	0.00000	.92639
8.98413	8.14140	-3.47500	0.00000	.80000	76.15267	0.00000	0.00000	-1.22786
7.29867	6.45594	-3.47500	0.00000	.80000	75.05450	0.00000	0.00000	-.18679
5.61322	4.77049	-3.47500	0.00000	.80000	73.77220	0.00000	0.00000	.27712
3.92776	3.08503	-3.47500	0.00000	.80000	72.25692	0.00000	0.00000	.59548
2.24230	1.39957	-3.47500	0.00000	.80000	70.44164	0.00000	0.00000	.83894
.55684	-.28589	-3.47500	0.00000	.80000	68.23250	0.00000	0.00000	1.04540
-1.12862	-1.97135	-3.47500	0.00000	.80000	65.49504	0.00000	0.00000	1.22673
-2.81407	-3.65680	-3.47500	0.00000	.80000	62.03241	0.00000	0.00000	1.37346
-4.49953	-5.34226	-3.47500	0.00000	.80000	57.55135	0.00000	0.00000	1.44994
-6.18499	-7.02772	-3.47500	0.00000	.80000	51.61343	0.00000	0.00000	1.47008
-7.87045	-8.71318	-3.47500	0.00000	.80000	43.58515	0.00000	0.00000	1.37511
-9.55591	-10.39864	-3.47500	0.00000	.80000	32.67174	0.00000	0.00000	1.06690
14.61296	13.54453	-1.82500	0.00000	.85000	76.12948	0.00000	0.00000	-1.79322
12.47611	11.40769	-1.82500	0.00000	.85000	74.91892	0.00000	0.00000	-.49145
10.33926	9.27084	-1.82500	0.00000	.85000	73.48326	0.00000	0.00000	.01232
8.20241	7.13399	-1.82500	0.00000	.85000	71.75572	0.00000	0.00000	.34472
6.06557	4.99714	-1.82500	0.00000	.85000	69.64157	0.00000	0.00000	.63008
3.92872	2.86030	-1.82500	0.00000	.85000	67.00296	0.00000	0.00000	.89202
1.79187	.72345	-1.82500	0.00000	.85000	63.63386	0.00000	0.00000	1.07662
-.34497	-1.41340	-1.82500	0.00000	.85000	59.21881	0.00000	0.00000	1.29709
-2.48182	-3.55025	-1.82500	0.00000	.85000	53.26834	0.00000	0.00000	1.48210
-4.61867	-5.68709	-1.82500	0.00000	.85000	45.03853	0.00000	0.00000	1.43684
-6.75552	-7.82394	-1.82500	0.00000	.85000	33.52982	0.00000	0.00000	1.49188
-8.89236	-9.96079	-1.82500	0.00000	.85000	17.94833	0.00000	0.00000	1.10695

28.73917	26.98750	-.48750	0.00000	.48750	83.55580	0.00000	0.00000	-1.27274
25.23583	23.48417	-.48750	0.00000	.48750	82.96210	0.00000	0.00000	-.31257
21.73250	19.98083	-.48750	0.00000	.48750	82.24863	0.00000	0.00000	-.00443
18.22917	16.47750	-.48750	0.00000	.48750	81.37542	0.00000	0.00000	-.06467
14.72583	12.97417	-.48750	0.00000	.48750	80.28260	0.00000	0.00000	-.09946
11.22250	9.47083	-.48750	0.00000	.48750	78.87666	0.00000	0.00000	.18986
7.71917	5.96750	-.48750	0.00000	.48750	77.00320	0.00000	0.00000	.55349
4.21583	2.46417	-.48750	0.00000	.48750	74.38960	0.00000	0.00000	.98033
.71250	-1.03917	-.48750	0.00000	.48750	70.51074	0.00000	0.00000	1.19378
-2.79083	-4.54250	-.48750	0.00000	.48750	64.23798	0.00000	0.00000	1.50910
-6.29417	-8.04583	-.48750	0.00000	.48750	52.82428	0.00000	0.00000	1.35073
-9.79750	-11.54917	-.48750	0.00000	.48750	29.47162	0.00000	0.00000	.86863

REF. CHORD	C AVERAGE	TRUE AREA	REFERENCE AREA	B/2	REF. AR	TRUE AR	MACH NUMBER
19.15500	15.56516	355.25921	320.68800	11.41200	1.62443	1.46635	.54000

CMQ= -.73161 CLQ= 1.75972

THIS CASE IS FINISHED

APPENDIX C

END OF FILE ENCOUNTERED AFTER CONFIGURATION 315

APPENDIX D

FORTRAN PROGRAM LISTING

This program was written in FORTRAN IV language, version 2.3, for the Control Data series 6000 computer systems with the SCOPE 3.0 operating system and library tape. Minor modifications may be required prior to use with other computers. The program requires $65{,}000_8$ words of storage on the Control Data 6600 computer system and consists of the main program, three overlays, and four subroutines. Each program or subroutine is identified in columns 73 to 76 by a 4-character identification. In addition, each of these parts is sequenced with a 4-digit number in columns 77 to 80. The following table is an index to the program listing:

Program or subroutine	Identification	Page
WINGTL	MAIN	95
INFSUB	INFS	96
GEOMTRY	GEOM	97
MATXSOL	MATX	106
AERODYN	AERO	108
CDICLS	CDIC	116
MATINV	MINV	118
FTLUP	TLUP	120

```
      OVERLAY(WINGTL,0,0)
      PROGRAM WINGTL(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      COMMON/ALL/ BOT,M,BETA,PTEST,QTEST,TBLSCW(50),Q(120),PN(120),
     1              PV(120),ALP(120),S(120),PSI(120),PHI(120),ZH(50)
      COMMON/TOTHRE/ CIR(120,2),SECTRST(50)
      COMMON/ONETHRE/TWIST(2),CREF,SREF,CAVE,CLDES,STRUE,AR,ARTRUE,
     1   RTCDHT(2),CONFIG,NSSWSV(2),MSV(2),KBOT,PLAN,IPLAN,MACH
     2   ,SSWWA(50)
      COMMON/MAINONE/ICODEOF,TOTAL,AAN(2),XS(2),YS(2),KFCTS(2)
     1        ,XREG(25,2),YREG(25,2),AREG(25,2),DIH(25,2),MCD(25,2)
     2        ,XX  (25,2),YY  (25,2),AS  (25,2),TTWD(25,2),MMCD(25,2)
     3        ,AN(2),ZZ (25,2)
    7 FORMAT(1H1//10X,I6,*HORSESHOE VORTICES LAIDOUT, THIS IS MORE THAN
     1THE 120 MAXIMUM. THIS CONFIGURATION IS ABORTED.*)
    8 FORMAT (1H1// 10X, I6 * ROWS OF HORSESHOE VORTICES LAIDOUT. THIS I
     1S MORE THAN THE 50 MAXIMUM. THIS CONFIGURATION IS ABORTED.* )
    9 FORMAT (1H1 // 10X, *PLANFORM* I6 * HAS* I6
     1 * BREAKPOINTS. THE MAXIMUM DIMENSIONED IS 25. THE CONFIGURATION I
     2S ABORTED.*)
C
C         VORTEX LATTICE AERODYNAMIC COMPUTATION
C                NASA-LRC PROGRAM NO. A2794
C
C
C
      ICODEOF=TOTAL=0
      WINGTL=6LWINGTL
      RECALL=6HRECALL
    1 CALL OVERLAY(WINGTL,1,0,RECALL)
      IF(ICODEOF.GT.0) GO TO 99
      IF(M.GT.120) GO TO 2
      NSW     = NSSWSV(1) + NSSWSV(2)
      IF  ( NSW.GT.50 )                GO TO 4
      ITSV  = 0
      DO 10 IT=1,IPLAN
      IF ( AN(IT).LE.25. )             GO TO 10
      WRITE (6,9)  IT,AN(IT)
      ITSV = 1
   10 CONTINUE
      IF (ITSV.GT.0)                   GO TO 5
      GO TO 3
    4 WRITE (6,8) NSW
      GO TO 5
    2 WRITE(6,7) M
      GO TO 5
    3 CALL OVERLAY(WINGTL,2,0,RECALL)
      CALL OVERLAY(WINGTL,3,0,RECALL)
    5 TOTAL=TOTAL-1.
      GO TO 1
   99 STOP
      END
```

```
      SUBROUTINE INFSUB (BOT,FUI,FVI,FWI)
      COMMON/INSUB23/PSII,APHII,XXX,YYY,ZZZ,SNN,TOLRNC
      FC =COS(PSII)
      FS =SIN(PSII)
      FT =FS/FC
      FPC=COS(APHII)
      FPS=SIN(APHII)
      FPT=FPS/FPC
      F1 =XXX+SNN*FT*FPC
      F2 =YYY+SNN*FPC
      F3 =ZZZ+SNN*FPS
      F4 =XXX-SNN*FT*FPC
      F5 =YYY-SNN*FPC
      F6 =ZZZ-SNN*FPS
      FFA=    (XXX**2+(YYY*FPS)**2+FPC**2*((YYY*FT)**2+(ZZZ/FC)**2-2.*
     1XXX*YYY*FT)-2.*ZZZ*FPC*(YYY*FPS+XXX*FT*FPS))
      FFB=(F1*F1+F2*F2+F3*F3)**.5
      FFC=(F4*F4+F5*F5+F6*F6)**.5
      FFD=F5*F5+F6*F6
      FFE=F2*F2+F3*F3
      FFF=(F1*FPC*FT+F2*FPC+F3*FPS)/FFB  -  (F4*FPC*FT+F5*FPC+F6*FPS)/
     1FFC
C
C
C
C
C     THE TOLERANCE SET AT THIS POINT IN THE PROGRAM MAY NEED TO BE
C     CHANGED FOR COMPUTERS OTHER THAN THE CDC 6000 SERIES
C
C
      IF(ABS(FFA).LT.(BOT*15.E-5)**2)  GO TO 262
      FUONE=(ZZZ*FPC-YYY*FPS)*FFF/FFA
      FVONE=(XXX*FPS-ZZZ*FT*FPC)*FFF/FFA
      FWONE=(YYY*FT-XXX)*FFF/FFA*FPC
      GO TO 265
  262 FUONE=FVONE=FWONE=0.
  265 IF(ABS(FFD).LT.TOLRNC) GO TO 263
C
      FVTWO= F6*(1.-F4/FFC)/FFC
      FWTWO=-F5*(1.-F4/FFC)/FFC
      GO TO 266
  263 FVTWO=FWTWO=0.
  266 IF(ABS(FFE).LT.TOLRNC) GO TO 264
C
      FVTHRE=-F3*(1.-F1/FFB)/FFE
      FWTHRE=F2*(1.-F1/FFB)/FFE
C
      GO TO 267
  264 FVTHRE=FWTHRE=0.
  267 FUI=FUONE
      FVI=FVONE+FVTWO+FVTHRE
      FWI=FWONE+FWTWO+FWTHRE
      RETURN
      END
```

```
      OVERLAY(WINGTL,1,0)
      PROGRAM GEOMTRY
      DIMENSION XREF(25),YREF(25),SAR(25),A(25),RSAR(25),X(25),Y(25),
     1          BOTSV(2),SA(2),VBORD(51),SPY(50,2),KFX(2),IYL(50,2),
     2          IYT(50,2)
      COMMON/ALL/ BOT,M,BETA,PTEST,QTEST,TBLSCW(50),Q(120),PN(120),
     1           PV(120),ALP(120),S(120),PSI(120),PHI(120),ZH(50)
      COMMON/ONETHRE/TWIST(2),CREF,SREF,CAVE,CLDES,STRUE,AR,ARTRUE,
     1   RTCDHT(2),CONFIG,NSSWSV(2),MSV(2),KBOT,PLAN,IPLAN,MACH
     2   ,SSWWA(50)
      COMMON/MAINONE/ICODEOF,TOTAL,AAN(2),XS(2),YS(2),KFCTS(2)
     1      ,XREG(25,2),YREG(25,2),AREG(25,2),DIH(25,2),MCD(25,2)
     2      ,XX  (25,2),YY  (25,2),AS  (25,2),TTWD(25,2),MMCD(25,2)
     3      ,AN(2),ZZ (25,2)
      REAL MACH
    1 FORMAT (1H1// 63X,*GEOMETRY DATA* )
    2 FORMAT (/// 45X ,A10, *REFERENCE PLANFORM HAS* I3 * CURVES* //
     1       12X *ROOT CHORD HEIGHT =*  F12.5 , 4X         *VARIABLE SWEEP
     2 PIVOT POSITION* 4X *X(S) =* F12.5,5X *Y(S) =* F12.5 //46X,
     3       *BREAK POINTS FOR THE REFERENCE PLANFORM * / )
    3 FORMAT (8F10.4)
    4 FORMAT (8F15.5)
    5 FORMAT  (1H1 // 47X , *CONFIGURATION NO.* ,F8.0 /  )
    6 FORMAT(2F12.5,2E12.5,F12.5)
    7 FORMAT(      //36X,I4,44H HORSESHOE VORTICES ON LEFT HALF OF THE W
     1ING/36X,I4,10H CHORDWISE,21X,I4,9H SPANWISE//)
    8 FORMAT (22X *POINT* 6X *X* 11X *Y* 11X *Z* 10X *SWEEP* 7X *DIHEDRA
     1L* 4X *MOVE* / 68X *ANGLE* 8X *ANGLE* 6X *CODE* /  )
    9 FORMAT(20X,I5,3F12.5,2F14.5, I6)
   10 FORMAT  ( / 40X, *CURVE* I3 * IS SWEPT* F12.5 * DEGREES ON PLANFOR
     1M* I3 )
   11 FORMAT(1H1///41X *END OF FILE ENCOUNTERED AFTER CONFIGURATION* F7)
   12 FORMAT (1H1///18X *THE FIRST VARIABLE SWEEP CURVE SPECIFIED (K =*
     1        I3 * ) DOES NOT HAVE AN M CODE OF 2 FOR PLANFORM* I4)
   13 FORMAT (8F5.1,F10.4,F5.1,F10.4)
   14 FORMAT(26X,I5,2F12.5,2F16.5,4X,I4)
   15 FORMAT (1H1 ///  X *ERROR - PROGRAM CANNOT PROCESS PTEST =* F5.1
     1 * AND QTEST =* F5.1 )
   16 FORMAT  ( // 48X , *BREAK POINTS FOR THIS CONFIGURATION* //)
   17 FORMAT (28X *POINT* 6X *X* 11X *Y* 11X *SWEEP* 10X *DIHEDRAL* 7X
     1 *MOVE* / 38X *REF* 9X *REF* 10X *ANGLE* 11X *ANGLE* 9X *CODE* / )
   18 FORMAT  (/   52X , *SECOND PLANFORM BREAK POINTS*  / )
   19 FORMAT(////25X,34HTHE BREAKPOINT LOCATED SPANWISE AT,F11.5,3X,20HH
     1AS BEEN ADJUSTED TO,F9.5////)
   20 FORMAT  (/  43X, F5 * HORSESHOE VORTICES IN EACH CHORDWISE ROW* )
   22 FORMAT(/23X*TABLE OF HORSESHOE VORTICES IN EACH CHORDWISE ROW (FR
     1M TIP TO ROOT BEGINNING WITH FIRST PLANFORM)*//25F5.0/25F5.0)
   24 FORMAT(///33XI5* HORSESHOE VORTICES USED ON THE LEFT HALF OF THE C
     1ONFIGURATION*//50X*PLANFORM        TOTAL          SPANWISE*/)
   25 FORMAT (52X, I4 , 10X , I3 , 11X , I4 )
C
C
C       PART ONE - GEOMETRY COMPUTATION
C
C                SECTION ONE - INPUT OF REFERENCE WING POSITION
C
C
C
      RTCDHT(1)=RTCDHT(2)=0.
      YTOL      = 1.E-10
```

```
      AZY         = 1.E+13
      PIT         = 1.5707963
      RAD         = 57.29578
      IF (TCTAL.GT.O.)  GC TO 80
C
C
C     SET PLAN EQUAL TO 1. FOR A WING ALCNE COMPUTAICN - EVEN FOR A
C     VARIABLE SWEEP WING
C     SET PLAN ECUAL TO 2. FOR A WING - TAIL COMBINATICN
C
C     SET TCTAL EQUAL TC THE NUMBER CF SETS
C       OF GROUP TWO DATA PRCVIDED
C
      READ (5,3) PLAN,TCTAL,CREF,SREF
      IF (ECF,5) 1CC6,4C
   40 IPLAN        =PLAN
C
C
C     SET AAN(IT) EQUAL TO THE MAXIMUM NUMBER OF CURVES REQUIREC TO
C     DEFINE THE PLANFORM PERIMETER CF THE (IT) PLANFCRM.
C
C     SET RTCDHT(IT) EQUAL TO THE ROCT CHCRD HEIGHT CF THE LIFTING
C     SURFACE (IT),WHOSE PERIMETER PCINTS ARE BEING REAC IN, WITH
C     RESPECT TO THE WING RCCT CHCRD HEIGHT
C
      WRITE (6,1)
      DO 58 IT = 1,IPLAN
      READ (5,3) AAN(IT),XS(IT),YS(IT),RTCDHT(IT)
      N           = AAN(IT)
      N1          = N + 1
      MAK         = 0
      IF (IPLAN.EQ.1)                     PRTCON = 10H
      IF (IPLAN.EC.2 .AND. IT.EQ.1 )      PRTCON = 10H     FIRST
      IF (IPLAN.EQ.2 .AND. IT.EQ.2 )      PRTCON = 10H    SECOND
      WRITE (6,2) PRTCON,N,RTCDHT(IT),XS(IT),YS(IT)
      WRITE(6,17)
      DO 59 I=1,N1
      READ (5,3)  XREG(I,IT) , YREG(I,IT), DIH(I,IT), AMCD
      MCD(I,IT) = AMCD
      IF (I.EQ.1)                         GO TO 59
      IF  ( MAK.NE.0 .OR. MCD(I-1,IT).NE.2 )      GO TO 49
      MAK    =  I-1
   49 IF  (ABS( YREG(I-1,IT)-YREG(I,IT)).LT.YTOL)GO TO 5C
      AREG(I-1,IT) = (XREG(I-1,IT)-XREG(I,IT))/(YREG(I-1,IT)-YREG(I,IT))
      ASWP = ATAN ( AREG(I-1,IT) ) * RAD
      GO TO 51
   50 YREG(I,IT) = YREG(I-1,IT)
      AREG( I-1,IT) = AZY
      ASWP          = 90.
   51 J           = I - 1
C
C     WRITE PLANFCRM PERIMETER PCINTS AND ANGLES
C
      WRITE (6,14)  J, XREG(J,IT),YREG(J,IT),ASWP,DIH(J,IT),MCD(J,IT)
      DIH(J,IT) =   TAN(DIH(J,IT)/RAD)
   59 CONTINUE
      KFCTS(IT) = MAK
      WRITE (6,14)  N1,XREG(N1,IT),YREG(N1,IT)
   58 CONTINUE
C
C                     PART 1 - SECTICN 2
```

```
C          READ GROUP 2 DATA AND COMPUTE DESIRED WING POSITION            GEOM1220
C                                                                         GEOM1230
C                                                                         GEOM1240
C     SCW MUST NOT BE SET EQUAL TO ZERO OR ONE WHEN THE WING HAS DIHEDRALGEOM1250
C                                                                         GEOM1260
C      SET SA(1),SA(2) EQUAL TO THE SWEEP ANGLE,IN DEGREES, FOR THE FIRSTGEOM1270
C      CURVE(S) THAT CAN CHANGE SWEEP FOR EACH PLANFORM                   GEOM1280
C                                                                         GEOM1290
C      IF A PARTICULAR VALUE OF CL IS DESIRED AT WHICH THE LOADINGS ARE   GEOM1300
C      TO BE COMPUTED, SET CLDES EQUAL TO THIS VALUE                      GEOM1310
C      SET CLDES EQUAL TO 11. FOR A DRAG POLAR AT CL VALUES OF-.1 TO  1.0GEOM1320
C                                                                         GEOM1330
C      IF PTEST IS SET EQUAL TO ONE THE PROGRAM WILL COMPUTE  CLP         GEOM1340
C      IF QTEST IS SET EQUAL TO ONE THE PROGRAM WILL COMPUTE  CMQ AND CLQGEOM1350
C      DO NOT SET BOTH PTEST AND QTEST TO ONE FOR A SINGLE CONFIGURATION GEOM1360
C                                                                         GEOM1370
C      SET TWIST(1) OR TWIST(2) EQUAL TO 0. FOR A FLAT PLANFORM AND TO 1.GEOM1380
C      FOR A PLANFORM THAT HAS TWIST AND/OR CAMBER                        GEOM1390
C                                                                         GEOM1400
   80 READ (5,13)CONFIG,SCW,VIC,MACH,CLDES,PTEST,QTEST,TWIST(1),SA(1),TWGEOM1410
     1IST(2),SA(2)                                                        GEOM1420
      WRITE(6,5) CONFIG                                                   GEOM1430
      IF (EOF,5) 1006,82                                                  GEOM1440
   82 IF  ( PTEST.NE.0. .AND. QTEST.NE.0. )  GO TO 1008                   GEOM1450
      IF  (SCW.EQ.0.)       GO TO 76                                      GEOM1460
      DO 74 I=1,50                                                        GEOM1470
   74 TBLSCW(I) = SCW                                                     GEOM1480
      GO TO 78                                                            GEOM1490
   76 READ (5,3) STA                                                      GEOM1500
      NSTA = STA                                                          GEOM1510
      READ (5,3) (TBLSCW(I),TBLSCW(I+1),TBLSCW(I+2),TBLSCW(I+3)          GEOM1520
     1                ,TBLSCW(I+4),TBLSCW(I+5),TBLSCW(I+6),TBLSCW(I+7),  GEOM1530
     2             I = 1,NSTA,8)                                          GEOM1540
   78 DO 100 IT = 1,IPLAN                                                 GEOM1550
      N          = AAN(IT)                                                GEOM1560
      N1         =  N + 1                                                 GEOM1570
      DO 83 I=1,N                                                         GEOM1580
      XREF(I)    = XREG(I,IT)                                             GEOM1590
      YREF(I)    = YREG(I,IT)                                             GEOM1600
      A    (I)   = AREG(I,IT)                                             GEOM1610
      RSAR(I)    = ATAN(A(I))                                             GEOM1620
      IF (A(I).EQ.AZY)         RSAR(I) = PIT                              GEOM1630
   83 CONTINUE                                                            GEOM1640
      XREF(N1)   = XREG(N1,IT)                                            GEOM1650
      YREF(N1)   = YREG(N1,IT)                                            GEOM1660
      IF ( KFCTS(IT) .GT. 0 )            GO TO 79                         GEOM1670
      K       = 1                                                         GEOM1680
      SA(IT)   = RSAR(1) * RAD                                            GEOM1690
      GO TO 77                                                            GEOM1700
   79 K        = KFCTS(IT)                                                GEOM1710
   77 WRITE (6,10) K,SA(IT),IT                                            GEOM1720
      SB         =   SA(IT)/RAD                                           GEOM1730
      IF ( ABS( SB - RSAR(K) ).GT. (.1/RAD) )     GO TO 111               GEOM1740
C     REFERENCE PLANFORM COORDINATES ARE STORED UNCHANGED FOR WINGS       GEOM1750
C             WITHOUT CHANGE IN SWEEP                                     GEOM1760
      DO 113 I=1,N                                                        GEOM1770
      X(I)=XREF(I)                                                        GEOM1780
      Y(I)=YREF(I)                                                        GEOM1790
      IF (RSAR(I) .EQ. PIT )             GO TO 114                        GEOM1800
      A(I)=TAN(RSAR(I))                                                   GEOM1810
      GO TO 113                                                           GEOM1820
```

```
  114 A(I)=AZY                                                         GEOM1830
  113 SAR(I)=RSAR(I)                                                   GEOM1840
      X(N1)=XREF(N1)                                                   GEOM1850
      Y(N1)=YREF(N1)                                                   GEOM1860
      GC TO 103                                                        GEOM1870
C                                                                      GEOM1880
C     CHANGES IN WING SWEEP ARE MADE HERE                              GEOM1890
C                                                                      GEOM1900
  111 IF (MCD(K,IT).NE.2)              GC TC 1007                      GEOM1910
      KA=K-1                                                           GEOM1920
      DO 81 I=1,KA                                                     GEOM1930
      X(I)=XREF(I)                                                     GEOM1940
      Y(I)=YREF(I)                                                     GEOM1950
   81 SAR(I)=RSAR(I)                                                   GEOM1960
C     DETERMINE LEADING EDGE INTERSECTION BETWEEN FIXED AND VARIABLE   GEOM1970
C             SWEEP WING SECTICNS                                      GEOM1980
      SAR(K)=SB                                                        GEOM1990
      A(K)   =  TAN(SB)                                                GEOM2000
      SAI=SB-RSAR(K)                                                   GEOM2010
      X(K+1)=XS+(XREF(K+1)-XS)*CCS(SAI)+(YREF(K+1)-YS)*SIN(SAI)        GEOM2020
      Y(K+1)=YS+(YREF(K+1)-YS)*CCS(SAI)-(XREF(K+1)-XS)*SIN(SAI)        GEOM2030
      IF ( ABS (SB - SAR(K-1) ) .LT. (.1/RAD) )            GC TC 84    GEOM2040
      Y(K)=X(K+1)-X(K-1)-A(K)*Y(K+1)+A(K-1)*Y(K-1)                     GEOM2050
      Y(K)=Y(K)/(A(K-1)-A(K))                                          GEOM2060
      X(K)= A(K)*X(K-1)-A(K-1)*X(K+1)+A(K-1)*A(K)*(Y(K+1)-Y(K-1))      GEOM2070
      X(K)=X(K)/(A(K)-A(K-1))                                          GEOM2080
      GC TO 85                                                         GEOM2090
C     ELIMINATE EXTRANEOUS BREAKPOINTS                                 GEOM2100
   84 X(K)=XREF(K-1)                                                   GEOM2110
      Y(K)=YREF(K-1)                                                   GEOM2120
      SAR(K)      =     SAR(K-1)                                       GEOM2130
   85 K=K+1                                                            GEOM2140
C     SWEEP THE BREAKPOINTS ON THE VARIABLE SWEEP PANEL                GEOM2150
C        (IT ALSO KEEPS SWEEP ANGLES IN FIRST OR FOURTH QUADRANTS)     GEOM2160
   86 K=K+1                                                            GEOM2170
      SAR(K-1)=SAI+RSAR(K-1)                                           GEOM2180
   99 IF ( SAR(K-1) .LE. PIT )         GO TO 102                       GEOM2190
      SAR(K-1)=SAR(K-1)-3.1415927                                      GEOM2200
      GC TO  99                                                        GEOM2210
  102 IF ( SAR(K-1) .GE.(-PIT))        GO TC 106                       GEOM2220
      SAR(K-1)=SAR(K-1)+3.1415927                                      GEOM2230
      GC TO 102                                                        GEOM2240
  106 IF(( SAR(K-1)).LT..C) GC TC 1C8                                  GEOM2250
      IF   ( SAR(K-1) - PIT )          90,87,87                        GEOM2260
  108 IF   ( SAR(K-1) + PIT )          89,89,90                        GEOM2270
   87 A(K-1)=AZY                                                       GEOM2280
      GC TO 91                                                         GEOM2290
   89 A(K-1)=-AZY                                                      GEOM2300
      GC TO 91                                                         GEOM2310
   90 A(K-1)=TAN(SAR(K-1))                                             GEOM2320
   91 KK          = MCD(K,IT)                                          GEOM2330
      GC TO (93,92),KK                                                 GEOM2340
   92 Y(K)=YS+(YREF(K)-YS)*COS(SAI)-(XREF(K)-XS)*SIN(SAI)              GEOM2350
      X(K)=XS+(XREF(K)-XS)*COS(SAI)+(YREF(K)-YS)*SIN(SAI)              GEOM2360
      GC TO 86                                                         GEOM2370
C     DETERMINE THE TRAILING EDGE INTERSECTION                         GEOM2380
C        BETWEEN FIXED AND VARIABLE SWEEP WING SECTIONS                GEOM2390
   93 IF (ABS (RSAR(K)-SAR(K-1)) .LT. (.1/RAD) )        GC TO 96       GEOM2400
      Y(K)=XREF(K+1)-X(K-1)-A(K)*YREF(K+1)+A(K-1)*Y(K-1)               GEOM2410
      Y(K)=Y(K)/(A(K-1)-A(K))                                          GEOM2420
      X(K)=A(K)*X(K-1)-A(K-1)*XREF(K+1)+A(K-1)*A(K)*(YREF(K+1)-Y(K-1)) GEOM2430
```

```
      X(K)=X(K)/(A(K)-A(K-1))
      GO TO 97
   96 X(K)=XREF(K+1)
      Y(K)=YREF(K+1)
   97 K=K+1
C     STORE REFERENCE PLANFORM COORDINATES ON INBOARD FIXED TRAILING
C     EDGE
      DO 98 I=K,N1
      X(I)=XREF(I)
      Y(I)=YREF(I)
   98 SAR(I-1)=RSAR(I-1)
  103 DO 101 I=1,N
      XX(I,IT)   = X(I)
      YY(I,IT)   = Y(I)
      MMCD(I,IT)= MCD(I,IT)
      TTWD(I,IT) = DIH(I,IT)
  101 AS  (I,IT) = A(I)
      XX(N1,IT)  = X(N1)
      YY(N1,IT)  = Y(N1)
      AN(IT)     = AAN(IT)
  100 CONTINUE
C
C       LINE UP BREAKPOINTS AMONG PLANFORMS
C
  299 BOTSV(1)=BOTSV(2)=0.
      WRITE (6,16)
      DO 180 IT=1,IPLAN
      NIT=AN(IT)+1
      DO 178 ITT=1,IPLAN
      IF (ITT.EQ.IT)   GO TO 178
      NITT=AN(ITT)+1
      DO 176 I=1,NITT
      JPSV=0
      DO 166 JP=1,NIT
      IF(YY(JP,IT) .EQ.YY(I,ITT))    GO TO 176
  166 CONTINUE
      DO 170 JP=1,NIT
      IF (YY(JP,IT).LT.YY(I,ITT))  GO TO 168
  170 CONTINUE
      GO TO 176
  168 JPSV = JP
      IND = NIT -(JPSV -1)
      DO 172 JP=1,IND
      K2 = NIT -JP +2
      K1 = NIT -JP +1
      XX(K2,IT) = XX(K1,IT)
      YY(K2,IT) = YY(K1,IT)
      MMCD(K2,IT)= MMCD(K1,IT)
      AS(K2,IT) = AS(K1,IT)
  172 TTWD(K2,IT)=TTWD(K1,IT)
      YY(JPSV,IT)  = YY(I,ITT)
      AS(JPSV,IT)  = AS(JPSV-1,IT)
      TTWD(JPSV,IT)= TTWD(JPSV-1,IT)
      XX(JPSV,IT)  = (YY(JPSV,IT) - YY(JPSV-1,IT)) * AS(JPSV-1,IT)
     1               +  XX(JPSV-1,IT)
      MMCD(JPSV,IT) = MMCD(JPSV-1,IT)
      AN(IT)  = AN(IT) + 1.
      NIT   = NIT + 1
  176 CONTINUE
  178 CONTINUE
C
```

```
C      SEQUENCE WING COORDINATES FROM TIP TO ROOT
C
       N1 = AN(IT)+ 1.
       DO 203 I=1,N1
   203 Q(I)     = YY(I,IT)
       DO 208 J=1,N1
       HIGH = 1.
       DO 205 I=1,N1
       IF (( Q(I)-HIGH).GE.0. )          GO TO 205
       HIGH     = Q(I)
       IH = I
   205 CONTINUE
       IF (J.NE.1) GO TO 206
       BOTSV(IT)   = HIGH
       KFX(IT)     = IH
   206 Q (IH)      = 1.
       SPY(J,IT)   = HIGH
       IF (IH.GT.KFX(IT))   GO TO 209
       IYL(J,IT) = 1
       IYT(J,IT) = 0
       GO TO 208
   209 IYL(J,IT) = 0
       IYT(J,IT) = 1
   208 CONTINUE
   180 CONTINUE
C
C      SELECT MAXIMUM B/2 AS THE WING SEMISPAN
C
       KBOT = 1
       IF (BOTSV(1).GE.BOTSV(2))  KBOT = 2
       BOT = BOTSV(KBOT)
C
C    COMPUTE NOMINAL HORSESHOE VORTEX WIDTH ALONG WING SURFACE
C
       TSPAN = 0
       ISAVE = KFX(KBOT) - 1
       I     = KFX(KBOT) - 2
   216 IF (I.EQ.0)                          GO TO 217
       IF(TTWD(I,KBOT).EQ.TTWD(ISAVE,KBOT)) GO TO 218
   217 CTWD  = COS( ATAN(TTWD(ISAVE,KBOT) ) )
       TLGTH = (YY(ISAVE+1,KBOT) - YY(I+1,KBOT) ) / CTWD
       TSPAN = TSPAN + TLGTH
       IF (I.EQ.0)                          GO TO 219
       ISAVE = I
   218 I     = I -1
       GO TO 216
   219 VI    = TSPAN / VIC
       VSTOL = VI / 2
C
C      ELIMINATE PLANFORM BREAKPOINTS WHICH ARE WITHIN (B/2)/2000 UNITS
C      LATERALLY
C
       DO 220 IT = 1,IPLAN
       N = AN(IT)
       N1= N + 1
       DO 220 J=1,N
       AA = ABS(SPY(J,IT) - SPY(J+1,IT) )
       IF ( AA.EQ.0. .OR. AA.GT.ABS(TSPAN/2000.))  GO TO 220
       IF ( AA.GT.YTOL)   WRITE(6,19) SPY(J+1,IT) , SPY(J,IT)
       DO 222 I=1,N1
       IF ( YY(I,IT).NE.SPY(J+1,IT))       GO TO 222
```

```
      YY(I,IT)   = SPY(J,IT)
  222 CONTINUE
      SPY(J+1,IT) = SPY(J,IT)
  220 CONTINUE
C
C     COMPUTE Z COORDINATES
C
      DO 236 IT=1,IPLAN
      JM   =   N1   = AN(IT) + 1.
      DO 230  JZ=1,N1
  230 ZZ(JZ,IT) = RTCDHT(IT)
      JZ          = 1
  232 JZ          = JZ + 1
      IF   (JZ.GT.KFX(IT))       GO TO 234
      ZZ(JZ,IT) = ZZ(JZ-1,IT) +(YY(JZ,IT) - YY(JZ-1,IT) ) *TTWD(JZ-1,IT)
      GO TO 232
  234 JM           = JM-1
      IF   ( JM.EQ.KFX(IT) )    GO TO 236
      ZZ(JM,IT) = ZZ(JM+1,IT) +(YY(JM,IT)-YY(JM+1,IT)) *TTWD(JM,IT)
      GO TO 234
  236 CONTINUE
C
C     WRITE PLANFORM PERIMETER POINTS ACTUALLY USED IN THE COMPUTATIONS
C
      WRITE (6,8)
      DO 240 IT =1,IPLAN
      N    = AN(IT)
      N1   = N + 1
      IF (IT.EQ.2)  WRITE (6,18)
      DO 238 KK=1,N
      TOUT   = ATAN ( TTWD(KK,IT) )* RAD
      AOUT   = ATAN(AS(KK,IT) )*RAD
      IF (AS(KK,IT).EQ.AZY)            AOUT=90.
      WRITE (6,9)    KK,XX(KK,IT), YY(KK,IT), ZZ(KK,IT), AOUT,
     1 TOUT ,MMCC(KK,IT)
  238 CONTINUE
      WRITE (6,9) N1,XX(N1,IT),YY(N1,IT),ZZ(N1,IT)
  240 CONTINUE
C
C     PART ONE - SECTION THREE - LAY OUT YAWED HORSESHOE VORTICES
C
      STRUE = 0.
      NSSWSV(1)   =   NSSWSV(2)   =   MSV(1) =   MSV(2)   =   0
  700 DO 722 IT=1,IPLAN
      N1      = AN(IT) + 1.
      I       =  0
      J       = 1
      YIN     = BOTSV(IT)
      ILE     = ITE    = KFX(IT)
C     DETERMINE SPANWISE BORDERS OF HORSESHOE VORTICES
  701 IXL     = IXT    = 0
      I       = I + 1
      IF(YIN.GE.(SPY(J,IT)+VSTOL) )     GO TO 703
C     BORDER IS WITHIN VORTEX SPACING TOLERANCE (VSTOL) OF BREAKPOINT
C     THEREFORE USE THE NEXT BREAKPOINT INBOARD FOR THE BORDER
      VBORD(I)   = YIN
      GO TO 707
C     USE NOMINAL VORTEX SPACING TO DETERMINE THE BORDER
  703 VBORD(I)   = SPY(J,IT)
C     COMPUTE SUBSCRIPTS ILE AND ITE TO INDICATE WHICH
C     BREAKPOINTS ARE ADJACENT AND WHETHER THEY ARE ON THE WING LEADING
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```
C        EDGE OR THE TRAILING EDGE
  715 IF (J.GE.N1)                            GO TO 706
      IF (SPY(J,IT).NE.SPY(J+1,IT))           GO TO 706
      IXL         = IXL + IYL(J,IT)
      IXT         = IXT + IYT(J,IT)
      J           = J + 1
      GO TO 715
  706 YIN         = SPY(J,IT)
      IXL         = IXL   +  IYL(J,IT)
      IXT         = IXT   +  IYT(J,IT)
      J           = J + 1
  707 CPHI        = COS ( ATAN ( TTWD(ILE,IT) ) )
      IPHI = ILE - IXL
      IF ( J.GE.N1 )       IPHI = 1
      YIN  =  YIN - VI* COS ( ATAN ( TTWD(IPHI,IT) ) )
      IF   (I.NE.1)                            GO TO 709
  708 ILE         = ILE - IXL
      ITE         = ITE + IXT
      GO TO 701
C     COMPUTE COORDINATES FOR CHORDWISE ROW OF HORSESHOE VORTICES
  709 YQ          = ( VBORD(I-1) + VBORD(I) ) / 2.
      HW          = ( VBORD(I)    - VBORD(I-1))/ 2.
      IM1         = I - 1 + NSSWSV(1)
      ZW(IM1)     = ZZ(ILE,IT) + ( YQ - YY(ILE,IT) ) * TTWD(ILE,IT)
      PHI(IM1)    = TTWD( ILE,IT)
      SSWWA(IM1) = AS(ILE,IT)
      XLE         = XX(ILE,IT) + AS(ILE,IT) * (YQ - YY(ILE,IT) )
      XTE         = XX(ITE,IT) + AS(ITE,IT) * (YQ - YY(ITE,IT) )
      XLOCAL      = ( XLE - XTE ) / TBLSCW(IM1)
C
C     COMPUTE WING AREA PROJECTED TO THE X - Y PLANE
C
      STRUE   =   STRUE + XLOCAL * TBLSCW(IM1) * (HW * 2.) * 2.
C
      NSCW        = TBLSCW(IM1)
      DO 720 JCW=1,NSCW
      AJCW        = JCW - 1
      XLEL        = XLE - AJCW * XLOCAL
      NTS     = JCW + MSV(1) + MSV(2)
      PN(NTS)     = XLEL - .25 * XLOCAL
      PV(NTS)     = XLEL - .75 * XLOCAL
      PSI(NTS)    =   ((XLE - PN(NTS))*AS(ITE,IT) + (PN(NTS) - XTE)*AS(ILE,
     1                 IT) ) / (XLE - XTE) * CPHI
      S(NTS)      = HW / CPHI
      Q(NTS)      = YQ
  720 CONTINUE
      MSV(IT)     = MSV(IT) + NSCW
C
C     TEST TO DETERMINE WHEN WING ROOT (Y=0) IS REACHED
      IF   ( VBORD(I) .LT. -0.)               GO TO 708
C
      NSSWSV(IT) =   I - 1
  722 CONTINUE
      M           = MSV(1) + MSV(2)
C
C     COMPUTE ASPECT RATIO  AND  AVERAGE CHORD
C
      BOT         = - BOT
      AR          = 4. * BOT * BOT / SREF
      ARTRUE      = 4. * BOT * BOT / STRUE
      CAVE        = STRUE / ( 2. * BOT )
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      BETA       = ( 1. -  MACH* MACH) ** .5                            GEOM4880
      NVTWO      = 0                                                    GEOM4890
      DO 354 IT=1,IPLAN                                                 GEOM4900
      NVONE      = 1 + (IT-1)*MSV(1)                                    GEOM4910
      NVTWO      = NVTWO + MSV(IT)                                      GEOM4920
      IF (TWIST(IT) .LE. 0. )            GO TO 350                      GEOM4930
      READ (5,3)  (ALP(NV),ALP(NV+1),ALP(NV+2),ALP(NV+3),ALP(NV+4),ALP(NVGEOM4940
     1              +5),ALP(NV+6),ALP(NV+7),NV=NVONE,NVTWO,8)           GEOM4950
      GO TO 354                                                         GEOM4960
  350 DO 351 NV = NVONE , NVTWO                                         GEOM4970
  351 ALP(NV)    =  0.                                                  GEOM4980
  354 CONTINUE                                                          GEOM4990
      WRITE (6,24) M                                                    GEOM5000
      WRITE (6,25) (IT,MSV(IT),NSSWSV(IT), IT=1,IPLAN)                  GEOM5010
      IF ( SCW.NE.0. ) WRITE (6,20) SCW                                 GEOM5020
      IF ( SCW.EQ.0. ) WRITE (6,22) (TBLSCW(I),I=1,NSTA)                GEOM5030
C                                                                       GEOM5040
C     APPLY PRANDTL-GLAUERT CORRECTION                                  GEOM5050
C                                                                       GEOM5060
      DO 360 NV = 1,M                                                   GEOM5070
      PSI(NV)    = ATAN(PSI(NV)/BETA)                                   GEOM5080
      PN (NV)    = PN(NV) / BETA                                        GEOM5090
  360 PV (NV)    = PV(NV) / BETA                                        GEOM5100
      RETURN                                                            GEOM5110
 1006 ICODECF    = 1                                                    GEOM5120
      WRITE(6,11)   CONFIG                                              GEOM5130
      RETURN                                                            GEOM5140
 1007 ICODECF    = 2                                                    GEOM5150
      WRITE(6,12)  K,IT                                                 GEOM5160
      RETURN                                                            GEOM5170
 1008 ICODECF    = 3                                                    GEOM5180
      WRITE (6,15) PTEST,QTEST                                          GEOM5190
      RETURN                                                            GEOM5200
      END                                                               GEOM5210
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```
      OVERLAY(WINGTL,2,0)
      PROGRAM MATXSOL
      DIMENSION YY(2),FU(2),FV(2),FW(2),FVN(120,120),IPIVOT(120),
     1          INDEX(120,2)
      COMMON/ALL/ BOT,M,BETA,PTEST,QTEST,TBLSCW(50),Q(120),PN(120),
     1             PV(120),ALP(120),S(120),PSI(120),PHI(120),ZH(50)
      COMMON/TOTHRE/ CIR(120,2),SECTRST(50)
      COMMON/INSUB23/APSI,APHI ,XX ,YYY,ZZ ,SNN,TOLC
C
C
C
C     PART 2 - COMPUTE CIRCULATION TERMS
C
C
C
      FPI   =  12.5663704
C
C
C     THE TOLERANCE SET AT THIS POINT IN THE PROGRAM MAY NEED TO BE
C     CHANGED FOR COMPUTERS OTHER THAN THE CDC 6000 SERIES
C
C
      TOLC=(BOT*15.E-05)**2
      DO 6667 NUU=1,120
      DO 6667 NUT=1,120
      FVN(NUU,NUT)=0.
 6667 CONTINUE
      DO 308 NV=1,M
      CIR(NV,1)= 12.5663704 * ALP(NV)
      CIR(NV,2)= 12.5663704
      IF (PTEST.NE.0.)   CIR(NV,2) = -1.0964155 * Q(NV) / BOT
      IF (QTEST.NE.0. )  CIR(NV,2) = -1.0964155 * PV(NV) *BETA
  308 CONTINUE
      IZZ=1
      NNV=TBLSCW(IZZ)
      DO 314 NV=1,M
      IZ=1
      NNN=TBLSCW(IZ)
      DO 316 NN=1,M
      APHI     = ATAN(PHI(IZ))
      APSI     = PSI(NN)
      XX=PV(NV)-PN(NN) $YY(1)=Q(NV)-Q(NN) $YY(2)=Q(NV)+Q(NN)
      ZZ=ZH(IZZ)-ZH(IZ)
      SNN        = S(NN)
      DO 261 I=1,2
      YYY        = YY(I)
      CALL INFSUB (BOT,FU(I),FV(I),FW(I))
      APHI=-APHI   $APSI=-APSI
  261 CONTINUE
      IF(PTEST.NE.0.) GO TO 342
      FVN(NV,NN)=FW(1)-FV(1)*PHI(IZ)+FW(2)-FV(2)*PHI(IZ)
      GO TO 312
  342 FVN(NV,NN)=FW(1)-FV(1)*PHI(IZ)-FW(2)+FV(2)*PHI(IZ)
  312 IF (NN.LT.NNN .OR. NN.EQ.M ) GO TO 316
      IZ=IZ+1
      NNN=NNN+TBLSCW(IZ)
  316 CONTINUE
      IF (NV.LT.NNV .OR. NV.EQ.M ) GO TO 314
      IZZ=IZZ+1
      NNV=NNV+TBLSCW(IZZ)
```

```
314 CONTINUE
    CALL MATINV(FVN,M,CIR,2,DETERM,IPIVOT,INDEX,120,ISCALE)
    IZZA  =  IZZ
    DO 320  NZ=1,IZZA
320 SECTRST(NZ) = 0.
    IZZ=1
    NNV=TBLSCW(IZZ)
    DO 614 NV=1,M
    IZ=1
    NNN=TBLSCW(IZ)
    VELIN  =  0.
    DO 616 NN=1,M
    APHI     = ATAN(PHI(IZ))
    APSI     = PSI(NN)
    XX=PN(NV)-PN(NN)
    YY(1) = Q(NV) - Q(NN)
    YY(2) = Q(NV) + Q(NN)
    ZZ=ZH(IZZ)-ZH(IZ)
    SNN          = S(NN)
    DO 661 I=1,2
    YYY          = YY(I)
    CALL INFSUB (BOT,FU(I),FV(I),FW(I))
    APHI=-APHI
    APSI=-APSI
661 CONTINUE
    VELIN  =   ((FW(1)+FW(2)) - (FV(1)+FV(2)) * TAN(APHI) )*CIR(NN,2)
   1        /FPI + VELIN
    IF (NN.LT.NNN .OR. NN.EQ.M ) GO TO 616
    IZ=IZ+1
    NNN=NNN+TBLSCW(IZ)
616 CONTINUE
    CTCP     = - (VELIN - 1. ) *2. * CIR(NV,2)
    SECTRST(IZZ) = SECTRST(IZZ) + CTCP
    IF (NV.LT.NNV .OR. NV.EQ.M ) GO TO 614
    IZZ=IZZ+1
    NNV=NNV+TBLSCW(IZZ)
614 CONTINUE
    RETURN
    END
```

```
      OVERLAY(WINGTL,3,0)
      PROGRAM AERODYN
      DIMENSION CPM(2),YCP(2),YY(2),VOU(120,2),UOU(120,2),FU(2),FV(2),
     1XTLEG(60),CHLFT(120,2),CLCC(120,2),YTLEG(50),SLDT(50),CLA(2),SUM(2
     2),AC(2),CH(2,50),CCAV(2,50),CLCL(2,50), CP(120),FW(2)
     3,DIFCIRS(25),YLEGSV(25),ZLEGSV(25),CLPT(120,2),CLPB(120,2)
      COMMON/ALL/ BOT,M,BETA,PTEST,QTEST,TBLSCW(50),Q(120),PN(120),
     1            PV(120),ALP(120),S(120),PSI(120),PHI(120),ZH(50)
      COMMON/TOTHRE/ CIR(120,2),SECTRST(50)
      COMMON/ONETHRE/TWIST(2),CREF,SREF,CAVE,CLDES,STRUE,AR,ARTRUE,
     1   RTCDHT(2),CONFIG,NSSWSV(2),MSV(2),KBOT,PLAN,IPLAN,MACH
     2   ,SSWWA(50)
      COMMON/THRECDI/SLOAD(3,50)
      COMMON/INSUB23/APSI,APHI ,XX ,YYY,ZZ ,SNN,TOLCSQ
    1 FORMAT (/ 12X, *SECOND PLANFORM HORSESHOE VORTEX DESCRIPTIONS* /
    3 FORMAT(6F12.5)
    4 FORMAT (1H1///58X,16HAERODYNAMIC DATA///54X,      *CONFIGURATION
     1NO.*F7.0 // )
    5 FORMAT(1H1,18X*COMPLETE CONFIGURATION*31X*WING-BODY CHARACTERISTIC
     1S* / 64X *LIFT*  9X *INDUCED DRAG (FAR FIELD SOLUTION)*//
     2 16X   AR   * CL     COMPUTED ALPHA*19X *CL(WB)* 7X *CDI AT CL(WB)*
     3 4X ,15HCDI/(CL(WB)**2) / 88X 12H(1/(PI*AR) = F8.5 * )*  )
    6 FORMAT (11X,2F15.5,15X,3F15.5)
    7 FORMAT(////4X,11H REF. CHORD,6X,25HC AVERAGE     TRUE AREA   ,2X
     1*REFERENCE AREA*9X*B/2*    8X,7HREF. AR,8X7HTRUE AR,4X,11HMACH NUMB
     2ER/)
    8 FORMAT(8F15.5)
   11 FORMAT (/// 47X *COMPLETE CONFIGURATION CHARACTERISTICS* //
     1 36X *CL ALPHA* 8X *CL(TWIST)  ALPHA AT CL=0     Y CP       CM/CL
     2     CMO* / 27X *PER RADIAN   PER DEGREE* / 24X,7F12.5 )
   12 FORMAT(//25X,*ADDITIONAL LOADING*/24X*WITH CL BASED ON S(TRUE)*
     1         /67X34HLOAD DUE  ADD. LOAD AT  BASIC LOAD3X,27HSPAN LOAD A
     2T    SL COEF FROM/8H STATION6X5H 2Y/B9X9H SL COEF ,4X8HCL RATIO,4X7
     3HC RATIO,7X,14HTO TWIST   CL=,F9.5,3X,7HAT CL=05X,26HDESIRED CL
     4 CHORD BD VOR/)
   13 FORMAT (/ 47X, *CONTRIBUTION OF THE SECOND PLANFORM TO SPAN LOAD D
     1ISTRIBUTION* / )
   15 FORMAT(4X,I4,F12.5,5X,3F12.5,3X,3F12.5,3X,2F12.5)
   16 FORMAT (1H1)
   18 FORMAT(////55X,21HTHIS CASE IS FINISHED)
   20 FORMAT(///5X*DELTA CP TERMS FROM LE TIP TO TE TIP THEN INBOARD
     1ENDING WITH THE TE OF ROOT CHORD *)
   21 FORMAT (      /54X*CMQ AND CLQ ARE COMPUTED*//)
   22 FORMAT(/38X*STATIC LONGITUDINAL AERODYNAMIC COEFFICIENTS ARE COMPU
     1TED*//)
   23 FORMAT (      /59X*CLP IS COMPUTED*//)
   24 FORMAT(8F15.5)
   25 FORMAT (/20X *X* 11X *X* 11X *Y* 11X *Z* 12X *S* 5X *C/4 SWEEP* 4X
     1 *DIHEDRAL* 2X *LOCAL ALPHA* 2X *DELTA CP AT DESIRED* /
     2 19X *C/4* 9X *3C/4* 42X *ANGLE*7X,*ANGLE* 4X,*IN RADIANS* 4X
     3  *CL =* F10.5  / )
  303 FORMAT(12X,9F12.5)
 1013 FORMAT(/47X*CONTRIBUTION OF THE SECOND PLANFORM TO THE CHORD OR DR
     1AG FORCE*/)
 1070 FORMAT  (////  30X, *INDUCED DRAG, LEADING EDGE THRUST AND SUCTION
     1 COEFFICIENT CHARACTERISTICS*/
     2 34X *COMPUTED AT ONE RADIAN ANGLE OF ATTACK FROM A NEAR FIELD SOL
     3UTION* //
     4 58X *SECTION COEFFICIENTS* 12X *CONTRIBUTIONS TO TOTAL COEF.*/
     5 92X *FROM EACH SPANWISE ROW* /
     6 38X *L. E. SWEEP* /
```

APPENDIX D

```
    7 15X *STATION* 9X * 2Y/B* 5X *ANGLE* 5X*CDII C/2B* 5X *CT C/2B*
    8  5X *CS C/2B* 8X*CDII* 9X *CT* 10X *CS* )
 1071 FORMAT  (10X ,I10, 5X, 8F12.5)
 1072 FORMAT  (/// 57X,*TOTAL COEFFICIENTS* //
    1 36X 12HCDII/CL**2 =  F10.5 ,5X *CT=* F10.5, 5X *CS=* F10.5 )
 1074 FORMAT(////10X*INVALID LEADING EDGE SWEEP BEING USED, THE COSINE -
    1* G14.5 * FOR THE* I5 * SPANWISE ROW. CS IS WRONG.*)
 4445 FORMAT(//////////56X,4HCLP=,F9.5////)
 4446 FORMAT(//////////42X,4HCMQ=,F9.5,10X,4HCLQ=,F9.5////)
C
C
C
C
C     PART 3 - COMPUTE OUTPUT TERMS
C
C
C
      RAD = 57.29578
      TWST    = TWIST(1) + TWIST(2)
      ALREF   = 1
C
C
C     THE TOLERANCE SET AT THIS POINT IN THE PROGRAM MAY NEED TO BE
C     CHANGED FOR COMPUTERS OTHER THAN THE CDC 6000 SERIES
C
C
      TOLC= .0100*BOT
      TOLCSQ = TOLC*TOLC
      QINF=1.
      NSSW=NSSWSV(1)+NSSWSV(2)
      IF(RTCDHT(1).NE.RTCDHT(2)) GO TO 794
      SUMPHI=0
      DO 801 J=1,NSSW
  801 SUMPHI=SUMPHI+ABS(PHI(J))
      IF(SUMPHI.EQ.0.) GO TO 921
C
C                            PART 3 - SECTION 1
C          COMPUTE LIFT AND PITCHING MOMENT FOR WINGS WITH DIHEDRAL
C
C
C     GEOMETRY FOR TIP TRAILING LEGS
C
  794 CPM(1)=CPM(2)=YCP(1)=YCP(2)=IM=CLT=CLNT=NSSW1=0
      NSSW2  =  NSSW3  =  NSSWSV(1) $L=1
      NSCW   =  MSV(1) / NSSWSV(1)
      GO TO 798
  796 NSSW1  =  NSSWSV(1)
      NSSW2  =  NSSW $NSSW3=NSSWSV(2)$L=NSSWSV(1)+1
      NSCW   =  MSV(2) / NSSWSV(2)
  798 I  =  IM + 1
      J  =  IM + 2
      IUU=2
      DIFFCR1=0.
      APHI=ATAN(PHI(I))
      TLX1=PN(I)-S(I)*TAN(PSI(I))
      TLX2=PN(J)-S(J)*TAN(PSI(J))
      CLFTLG=TLX1-TLX2
      XTLEG(1)=TLX1/2.+TLX2/2.
      YLEG=Q(I)-S(I)*COS(APHI)
      IF(NSSW1.EQ.0) YLEGSV(  1)=YLEG
      ZLEG=ZH(I)-S(I)*SIN(APHI)
      IF(NSSW1.EQ.0) ZLEGSV( 1 )=ZLEG
```

```
      IF(NSSW1.EQ.NSSWSV(1)) GO TO 850
      GO TO 852
  850 DO 5050 IT=1,L
      IF((ABS(YLEGSV(IT)-YLEG).LT.TOLC).AND.(ABS(ZLEGSV(IT)-ZLEG).LT.TOL
     1C)) DIFFCR1=DIFCIRS(IT)
 5050 CONTINUE
  852 DO 802 NV=2,NSCW
      NVT=NV-1
  802 XTLEG(NV)=XTLEG(NVT)-CLFTLG
      NCTL=0  $NA=1  $NB=NSCW
  803 DO 823 NV=NA,NB
      VOU(NV,1)=VOU(NV,2)=UOU(NV,1)=UOU(NV,2)=0.
      DO 809 NN=1,M
      IZ=(NN-1)/NSCW+1
      APHI=ATAN(PHI(IZ))
      APSI=PSI(NN)
      XX=XTLEG(NV)-PN(NN)
      YY(1)=YLEG-Q(NN)
      YY(2)=YLEG+Q(NN)
      ZZ=ZLEG  -ZH(IZ)
      SNN    =   S(NN)
C
      DO 822 I=1,2
      YYY    =  YY(I)
      CALL  INFSUB (BOT,FU(I),FV(I),FW(I) )
      APHI=-APHI     $APSI=-APSI
  822 CONTINUE
C
 9001 DO 809 IXX=1,2
      UOU(NV,IXX)=UOU(NV,IXX)+((FU(1)+FU(2))*CIR(NN,IXX))/12.566371
  809 VOU(NV,IXX)=VOU(NV,IXX)+((FV(1)+FV(2))*CIR(NN,IXX))/12.566371
  823 CONTINUE
      NCTL=NCTL+1
      IF (NCTL-2)      810,811,812
C
C     GEOMETRY FOR SPANWISE BOUND VORTICES
C
  810 NA=NSCW+1
      NB=2*NSCW
      JA=IM*NSCW+1
      YLEG=Q(JA)
      ZLEG=ZH(IM+1)
      DO 818 J=1,NSCW
      JK=IM*NSCW+J
      NV=J+NSCW
  818 XTLEG(NV)=PN(JK)
      GO TO 803
C
C     GEOMETRY ALONG RIGHT TRAILING LEGS
C
  811 NA=2*NSCW+1
      NB=3*NSCW
      DIFFCR2=0.
      JK=IM*NSCW+1
      APHI=ATAN(PHI(IM+1))
      YLEG=Q(JK)+S(JK)*COS(APHI)
      IF(NSSW1.EQ.0) YLEGSV(IUU)=YLEG
      ZLEG=ZH(IM+1)+S(JK)*SIN(APHI)
      IF(NSSW1.EQ.0) ZLEGSV(IUU)=ZLEG
      TLX1=PN(JK)+S(JK)*TAN(PSI(JK))
      JK=JK+1
```

```
      TLX2=PN(JK)+S(JK)*TAN(PSI(JK))
      CRTTLG=TLX1-TLX2
      XTLEG(NA)=TLX1/2.+TLX2/2.
      NAA=NA+1
      IF(NSSW1.EQ.NSSWSV(1)) GO TO 851
      GO TO 853
  851 DO 5051 IT=1,L
      IF((ABS(YLEGSV(IT)-YLEG).LT.TOLC).AND.(ABS(ZLEGSV(IT)-ZLEG).LT.TCL
     1C)) DIFFCR2=DIFCIRS(IT)
 5051 CONTINUE
  853 DO 819 NV=NAA,NB
      NVT=NV-1
  819 XTLEG(NV)=XTLEG(NVT)-CRTTLG
      GO TO 803
C
C     COMPUTE LIFT AND PITCHING MOMENT FOR EACH ELEMENTAL PANEL
C
  812 YY(1)=YY(2)=0
      IF ( IM.NE.NSSW1 ) GO TO 834
      DO 835 IXX=1,2
      DIFCIR=DIFFCR1
      DO 835 NPOS=1,NSCW
      DIFCIR=DIFCIR+CIR(NPOS,IXX)
      CON=1.
      IF (NPOS.EQ.NSCW)   CON=.75
      CHLFT(NPOS,IXX)=CLFTLG*CON*DIFCIR*VOU(NPOS,IXX)*(2./SREF)
      CLPT(NPOS,IXX)=CHLFT(NPOS,IXX)*(Q(NPOS)-S(NPOS))*2.
  835 CONTINUE
      IF(NSSW1.EQ.0) DIFCIRS( 1 )=DIFCIR
  834 DO 815 IXX=1,2
      DIFCIR=DIFFCR2
      DO 815 NPOS=1,NSCW
      JK=IM*NSCW+NPOS
      JL=(IM+1)*NSCW+NPOS
      JM=NSCW+NPOS
      JN=2*NSCW+NPOS
      IF (IM.EQ.(NSSW2-1))  GO TO 836
      DIFCIR=DIFCIR+CIR(JL,IXX)-CIR(JK,IXX)
  836 CON=1.
      IF (NPOS.EQ.NSCW)  CON=.75
      CHLFT(JL,IXX)=CRTTLG*CON*DIFCIR*VOU(JN,IXX)*(2./SREF)
      CLCC(JK,IXX)=(2./SREF)*CIR(JK,IXX)*2.*S(JK)*COS(APHI)* (1.-UCU(JM,
     1IXX)+VOU(JM,IXX)*TAN(PSI(JK)))
      CLPB(JK,IXX)=CLCC(JK,IXX)*Q(JK)*2.
      CLPT(JL,IXX)=CHLFT(JL,IXX)*(Q(JK)+S(JK))*2.
      YY(IXX)=YY(IXX)+(CLCC(JK,IXX)+CHLFT(JK,IXX))*2.
      CPM(IXX)=CPM(IXX)+(CLCC(JK,IXX)*XTLEG(JM)*BETA+CHLFT(JK,IXX)*XTLEG
     1(NPOS)*BETA)*2./CREF
      YCP(IXX)=YCP(IXX)+(CLCC(JK,IXX)*Q(JK)+CHLFT(JK,IXX)*(Q(JK)-S(JK)*
     1COS(APHI)))/BOT
  815 CONTINUE
      IF(NSSW1.EQ.0) DIFCIRS(IUU)=DIFCIR
      CLT=CLT+YY(1)
      CLNT=CLNT+YY(2)
      IM=IM+1
      IF(NSSW1.EQ.0) IUU=IM+2
      IF(IM.EQ.NSSWSV(1)) CLWNGT=CLT
      IF(IM.EQ.NSSWSV(1)) CLWING=CLNT
      IF (IM.GE.NSSW2)       GO TO 816
      NCTL=1
      DO 817 IXX=1,2
```

```
      DO 817 NV =1,NSCW
      NY=NV+2*NSCW
      XTLEG(NV)=XTLEG(NY)
  817 VOU(NV,IXX)=VOU(NY,IXX)
      GO TO 810
C
C           SUM LIFT AND PITCHING MOMENT FOR ENTIRE WING
C
  816 YY(1)=CLT*SREF/STRUE
      YY(2)=CLNT*SREF/STRUE
      NUP=NSSW3 + 1
      YTLEG(NUP)=0.
      XTLEG(NUP)=0
      IND=1
      IF (TWST .EQ.0.)  IND=2
      DO 837 IXX=IND,2
      DO 820 JSSW=L,NSSW2
      SLOAD(IXX,JSSW)=0
      SLDT(     JSSW)=0
      APHI=ATAN(PHI(JSSW))
      JL=(JSSW-1)*NSCW+1
      K=JSSW-L+1
  820 YTLEG( K  )=Q(JL)-S(JL)*COS(APHI)
      DO 837 INC=1,NSCW
      DO 838 JNS=L,NSSW2
      JK=(JNS-1)*NSCW+INC
      K=JNS-L+1
  838 XTLEG( K )=CHLFT(JK,IXX)
      DO 837 INS=L,NSSW2
      JK=(INS-1)*NSCW+INC
      APHI=ATAN(PHI(INS))
      CALL  FTLUP (Q(JK),CHTLF,+1,NUP,YTLEG,XTLEG)
      T= SREF/(2.*S(JK)*COS(APHI)*CAVE)
      SLDT(INS)=SLDT(INS)+CHTLF*T
      CLCC(JK,IXX) = (CLCC(JK,IXX) + CHTLF ) * T
  837 SLOAD(IXX,INS)=SLOAD(IXX,INS)+ CLCC(JK,IXX)
      IF (IM.NE.NSSW)  GO TO 796
      CLA(2)=CLNT /ALREF
      CMCL=CPM(2)/CLNT
      CMO=CPM(1)-CMCL*CLT
      YCP(2)=YCP(2)/(CLNT/2.)
      DO 840 I=1,NSSW
      SLDT(I)=SLDT(I)/YY(2)
      IF (TWST .EQ.0.)  SLOAD(1,I)=0.
      IF (TWST .NE.0.)  SLOAD(1,I)=SLOAD(1,I)/YY(1)
  840 SLOAD(2,I) = SLOAD(2,I)/YY(2)
      CRL=0.
      DO 860 IAM=1,M
  860 CRL=CRL+CLPB(IAM,2)+CLPT(IAM,2)
      CLP=CRL/(.08725*2.*BOT)
      GO TO 903
C
C                                  PART 3 - SECTION 2
C           COMPUTE LIFT AND PITCHING MOMENT FOR WINGS WITHOUT DIHEDRAL
C
  921 DO 901 NV=1,2
      SUM(NV)=0
      DO 901 I=1,M
      SUM(NV)=SUM(NV)+CIR(I,NV)*S(I)
      IF (NV.EQ.1.AND.I.EQ.MSV(1) )    CLWNGT = SUM(1)*8. / SREF
      IF (NV.EQ.2.AND.I.EQ.MSV(1) )    CLWING = SUM(2)*8. / SREF
```

```
  901 CONTINUE
      CLT    = 8.* SUM(1)/SREF
      CLNT   = 8.* SUM(2)/SREF
      IF (KBOT.EQ.1)                         GO TO 800
      CLWNGT = CLT - CLWNGT
      CLWING = CLNT- CLWING
  800 CRI    = 0.
      DO 905 I=1,M
      CRI=CRI +(Q(I)*CIR(I,2)*2.*S(I))*2.
      CLCC(I,1)=CIR(I,1)*2./CAVE
  905 CLCC(I,2)=CIR(I,2)*2./CAVE
C
C     COMPUTE CLP
C
      CLP=    CRI /(SREF*BOT*0.08725)
      CLA(2)=CLNT
      DO 922 IXX=1,2
      SA=SB=SC=0.
      I       = 0
      DO 920 JSSW=1,NSSW
      SLDT(JSSW)=0
      SLOAD(IXX,JSSW)=0
      NSCW    = TBLSCW(JSSW)
      DO 920 JSCW=1,NSCW
      IF(TWST .EQ.0..AND.IXX.EQ.1) GO TO 930
      I       = I + 1
      SA=SA+CIR(I,IXX)*S(I)
      SB=SB+CIR(I,IXX)*Q(I)*S(I)
      SC=SC+CIR(I,IXX)*PN(I)*S(I)*BETA
      SLOAD(IXX,JSSW) = SLOAD(IXX,JSSW)+(BOT*CIR(I,IXX))/(2.*SUM(IXX))
      GO TO 920
  930 SLOAD(1,JSSW)=0.
  920 CONTINUE
      IF(TWST .EQ.0..AND.IXX.EQ.1) GO TO 932
      YCP(IXX)=SB/(SA*BOT)
      AC(IXX)=SC/(SA*CREF)
      GO TO 922
  932 YCP(1)=AC(1)=0.
  922 CONTINUE
      CMCL=AC(2)
      CMO=(AC(1)-AC(2))*CLT
C
C                            PART 3 - SECTION 3
C          COMPUTE AND PRINT FINAL OUTPUT DATA FOR ALL WINGS
C
  903 DO 902 IXX=1,2
      JN      = 0
      DO 902 JSSW=1,NSSW
      CH    (IXX,JSSW)=0
      NSCW     = TBLSCW(JSSW)
      DO 904 JSCW=1,NSCW
      JN       = JN + 1
      CH    (IXX,JSSW)=(-2.0)*(PV(JN)-PN(JN))*BETA+CH    (IXX,JSSW)
  904 CONTINUE
      CCAV(IXX,JSSW)=CH(IXX,JSSW)/CAVE
      CLCL(IXX,JSSW)=SLOAD(IXX,JSSW)/CCAV(IXX,JSSW)
  902 CONTINUE
      CLD=CLDES
      IF(CLDES.EQ.11) CLD=1.
      DO 1020 I=1,M
      CP(I)    = (CLCC(I,1)+CLCC(I,2)*(CLD  -CLT)/CLNT)*CAVE/(2.*(PN(I)-
```

```
     1            PV(I) ) * BETA )
 1020 CONTINUE
      WRITE (6,4)    CONFIG
      IF   ( PTEST.NE.0. )                        WRITE (6,23)
      IF   ( QTEST.NE.0. )                        WRITE (6,21)
      IF   ( PTEST.EQ.0. .AND. QTEST.EQ.0. )      WRITE (6,22)
      WRITE(6,25) CLD
      HEAD = 8HDESIRED
      IF (CLDES.EQ.11. )     HEAD = 8H
      IEND = 11
      IF(CLDES.NE.11.) IEND=1
      DO 5000 IUTK=1,IEND
      IF(IEND.EQ.11) CLDES=(FLOAT(IUTK)-1.)/10.
      IF(CLDES.EQ.0.) CLDES=-.)
      NR        = 0
      DO 3006 NV=1,NSSW
      NSCW      = TBLSCW(NV)
      NP        = NR + 1
      NR        = NR + NSCW
      PHIPR  =  ATAN(PHI(NV)) * RAD
      SLOAD(3,NV)=0.
      IF (NV.EQ. (NSSWSV(1) + 1) )      WRITE (6,1)
      DO 3006 I=NP,NR
      IF ( IUTK.GT.1 )                   GO TO 3006
      PNPR  = PN(I) * BETA
      PVPR  = PV(I) * BETA
      PSIPR = PSI(I)* RAD
      WRITE (6,303) PNPR,PVPR,Q(I),ZH(NV),S(I),PSIPR,PHIPR,ALP(I),CP(I)
 3006 SLOAD(3,NV)=SLOAD(3,NV)+CLCC(I,2)*CLDES/CLNT+CLCC(I,1)-CLCC(I,2)*C
     1LT/CLNT
      IF(IUTK.GT.1) GO TO 3007
      WRITE (6,7)
      WRITE (6,8) CREF,CAVE,STRUE,SREF, BCT,AR,ARTRUE,MACH
 3007 CONTINUE
C
C
      IF(PTEST.NE.0.)WRITE(6,4445) CLP
      IF(PTEST.NE.0.) GO TO 4444
C
C     COMPUTE CMQ,CLQ
C
      CMQ=2.0*CMCL*CLNT/(0.08725*CREF)
      CLQ=2.0*CLNT/(0.08725*CREF)
      IF(QTEST.NE.0.) WRITE(6,4446) CMQ,CLQ
      IF(QTEST.NE.0.) GO TO 4444
C
C           COMPUTE INDUCED DRAG
C
      NSV=NSSWSV(1)+1
      MTOT=MSV(1)+1
      IF(KBOT.EQ.1)                    GO TO 1001
      NSV=NSV+NSSWSV(2)
      MTOT=MTOT+MSV(2)
 1001 CALL CDICLS     (AR,ARTRUE,NSSWSV(KBOT),MTOT,NSV,CDI,CDIT)
      CLAPD=CLA(2)/57.29578
      ALPO=-(CLT/CLA(2))*57.29578
      ALPD=CLDES/CLAPD+ALPO
      ALPW=1./CLAPD
      CLWB=CLWING*ALPD/57.29578+CLWNGT
      CDIWB = CDI /(CLWB*CLWB)
      IF (IUTK.EQ.1)  WRITE (6,5) HEAD,CDIT
```

```
5000 WRITE (6,6) CLDES,ALPD,CLWB,CDI,CDIWB
     WRITE(6,11) CLA(2),CLAPD,CLT,ALPO,YCP(2),CMCL,CMO
     WRITE(6,12) CLT
     NR   = J = 0
     DO 1004 NV=1,NSSW
     BCLCC=BADLAE=BASLD=0.
     NSCW     = TBLSCW(NV)
     NP       = NR + 1
     NR       = NR + NSCW
     DO 1002 I=NP,NR
     ADLAE=CLCC(I,2)*CLT/CLNT
     BSLD=CLCC(I,1)-ADLAE
     BCLCC=BCLCC+CLCC(I,1)
     BADLAE=BADLAE+ADLAE
     BASLD=BASLD+BSLD
1002 CONTINUE
     J        = J + NSCW
     YQ       = Q(J) / BOT
     IF (NV.EQ.(NSSWSV(1)+1))  WRITE(6,13)
1004 WRITE(6, 15) NV,YQ,SLOAD(2,NV),CLCL(2,NV),CCAV(2,NV),BCLCC,BADLAE,
    1  BASLD,SLOAD(3,NV),SLDT(NV)
     WRITE (6,1070)
     CTHRUST = CSUCT = CDRAG =0.
     NN=1
     DO 1050 NV=1,NSSW
     SSCTRST = SECTRST(NV) / (4.*BOT)
     SSCDRAG = SLOAD (2,NV) * CAVE * SREF * CLA(2) / (STRUE * 4. * BOT)
    1          - SSCTRST
     CSSWWA  = COS ( ATAN (SSWWA(NV)))
     SSCSUCT = SSCTRST      / CSSWWA
     IF (NV.EQ.1)  GO TO 1060
     NN   = NN + TBLSCW(NV-1)
1060 PHIPR   =   ATAN (PHI(NV))
     CDRAGS   = SSCDRAG*4.*BOT*2.*S(NN)*COS(PHIPR)/SREF
     CDRAG    = CDRAG    + 2.0 * CDRAGS
     CTHRUSS = SECTRST(NV)*2.*S(NN)*COS(PHIPR) / SREF
     CTHRUST = CTHRUST + 2.0 * CTHRUSS
     CSUCTS  = CTHRUSS / CSSWWA
C    IF THE ABSOLUTE VALUE OF THE LEADING EDGE SWEEP ANGLE IS GREATER
C    THAN 80 DEGREES NO SUCTION CONTRIBUTION IS COMPUTED
     IF ( CSSWWA .LT. 0.17365 )    CSUCTS = 0.
     IF ( CSSWWA .LT. 0. )         WRITE (6,1074) CSSWWA,NV
     CSUCT    = CSUCT    + 2.0 * CSUCTS
     SWALE    = ATAN(SSWWA(NV)) * RAD
     YQ       = Q(NN)/ BOT
     IF(NV.EQ.(NSSWSV(1)+1)) WRITE(6,1013)
1050 WRITE (6,1071) NV,YQ,SWALE,SSCDRAG,SSCTRST,SSCSUCT,CDRAGS,CTHRUSS,
    1                CSUCTS
     CDRAGP   =  CDRAG / (CLA(2)*CLA(2))
     WRITE (6,1072) CDRAGP,CTHRUST,CSUCT
4444 WRITE(6,18)
     WRITE(6,16)
     RETURN
     END
```

```
      SUBROUTINE CDICLS     (AR,ARTRUE,ISEMSP,MTOT,NSV,CDI,CDIT)
      DIMENSION ETAN(51),GAMPR(51,1),ETA(41),GAMMA(41),VE(41),B(41),
     1FVN(41,41)
      COMMON/ALL/ ROT,M,BETA,PTEST,QTEST,TBLSCW(50),Q(120),PN(120),
     1             PV(120),ALP(120),S(120),PSI(120),PHI(120),ZH(50)
      COMMON/THRECDI/SLOAD(3,50)
      DO 15 I=1,41
      DO 15 J=1,41
   15 FVN(I,J)=0
      SPAN=2.*ROT
      CAVB=SPAN/ARTRUE
      PI=.314159265E+01
      NST=ISEMSP+1
      NN=MTOT
      DO 101 N=1,ISEMSP
      NM=NSV - N
      NSCW=TBLSCW(NM)
      NN=NN-NSCW
      ETAN(N)=ASIN(-Q(NN)*2./SPAN)
      GAMPR(N,1)=SLOAD(3,NM)*CAVB/(2.*SPAN)
  101 CONTINUE
      ETAN(NST)= PI/2.
      GAMPR(NST,1)=0
      DO 7 NP= 1,41
      ANP=NP
    7 ETA(NP)=     (ANP-21.)*PI/42.

      DO 102 JK=21,41
      CALL FTLUP(ETA(JK),GAMMA(JK),1,NST,ETAN,GAMPR)
  102 CONTINUE
      DO 600 NY=22,41
      ETA(NY)=SIN(ETA(NY))
      NR=42-NY
      ETA(NR)=-ETA(NY)
  600 GAMMA(NR)=GAMMA(NY)
      DO 589 NU=21,41
      ANU=NU
      DO 14 N=1,41
      AN=N
      NNUD=IABS(N-NU)
      VE(N)=COS(((AN-21.)*PI)/42.)
      IF(NNUD.NE.0) GO TO 9
      B(N)=(42.)/(4.0*COS(((ANU-21.)*PI)/42.))
      GO TO 14
    9 IF(MOD(NNUD,2).EQ.0) GO TO 12
      B(N)=VE(N)/((42.)*(ETA(N)-ETA(NU))**2)
      GO TO 14
   12 B(N)=0.0
   14 CONTINUE
      DO 589 NP=21,41
      NUST =IABS(NU-21)
      IF(NUST.EQ.0) GO TO 589
      IF(MOD(NUST,2).EQ.0) GO TO 589
      NPST=IABS(NP-20)
      IF(MOD(NPST,2).EQ.0) GO TO 589
      NPNUD=IABS(NP-NU)
      IF(NPNUD.EQ.0) GO TO 589
      IF(MOD(NPNUD,2).EQ.0) GO TO 589
      FVN(NU,NP)=2.0*B(NP)/21.*COS((ANU-21.)*PI/42.)
      IT=42-NU
```

```
      ITT=42-NP
      FVN(NU,ITT)=2.0*B(ITT)/21.*COS((ANU-21.)*PI/42.)
      FVN(IT,NP)=FVN(NU,ITT)
      FVN(IT,ITT)=FVN(NU,NP)
  589 CONTINUE
      CCC=0.0
      DO 10 N=1,41
   10 CCC=CCC+(GAMMA(N)*GAMMA(N))
      CCD=0.0
      DO 11 NUP=1,41
      DO 11 N=1,41
      CCD=CCD-2.0*FVN(NUP,N)*(GAMMA(NUP)*GAMMA(N))
   11 CONTINUE
      CDI=PI*AR/4.*(CCC+CCD)
      CDIT=1./(PI*AR)
      RETURN
      END
```

```
      SUBROUTINE MATINV(A,N,B,M,DETERM,IPIVOT,INDEX,NMAX,ISCALE)
C******** DOCUMENT DATE 08-01-68   SUBROUTINE REVISED 08-01-68 *********
C
C     MATRIX INVERSION WITH ACCOMPANYING SOLUTION OF LINEAR EQUATIONS
C
      DIMENSION IPIVOT(N),A(NMAX,N),B(NMAX,M),INDEX(NMAX,2)
      EQUIVALENCE (IROW,JROW), (ICOLUM,JCOLUM), (AMAX, T, SWAP)
C
C     INITIALIZATION
C
    5 ISCALE=0
    6 R1=10.0**100
    7 R2=1.0/R1
   10 DETERM=1.0
   15 DO 20 J=1,N
   20 IPIVOT(J)=0
   30 DO 550 I=1,N
C
C     SEARCH FOR PIVOT ELEMENT
C
   40 AMAX=0.0
   45 DO 105 J=1,N
   50 IF (IPIVOT(J)-1) 60, 105, 60
   60 DO 100 K=1,N
   70 IF (IPIVOT(K)-1) 80, 100, 740
   80 IF (ABS(AMAX)-ABS(A(J,K)))85,100,100
   85 IROW=J
   90 ICOLUM=K
   95 AMAX=A(J,K)
  100 CONTINUE
  105 CONTINUE
      IF (AMAX) 110,106,110
  106 DETERM=0.0
      ISCALE=0
      GO TO 740
  110 IPIVOT(ICOLUM)=IPIVOT(ICOLUM)+1
C
C     INTERCHANGE ROWS TO PUT PIVOT ELEMENT ON DIAGONAL
C
  130 IF (IROW-ICOLUM) 140, 260, 140
  140 DETERM=-DETERM
  150 DO 200 L=1,N
  160 SWAP=A(IROW,L)
  170 A(IROW,L)=A(ICOLUM,L)
  200 A(ICOLUM,L)=SWAP
  205 IF(M) 260, 260, 210
  210 DO 250 L=1, M
  220 SWAP=B(IROW,L)
  230 B(IROW,L)=B(ICOLUM,L)
  250 B(ICOLUM,L)=SWAP
  260 INDEX(I,1)=IROW
  270 INDEX(I,2)=ICOLUM
  310 PIVOT=A(ICOLUM,ICOLUM)
      IF (PIVOT) 1000,106,1000
C
C     SCALE THE DETERMINANT
C
 1000 PIVOTI=PIVOT
 1005 IF(ABS(DETERM)-R1)1030,1010,1010
 1010 DETERM=DETERM/R1
```

```
      ISCALE=ISCALE+1
      IF(ABS(DETERM)-R1)1060,1020,1020
 1020 DETERM=DETERM/R1
      ISCALE=ISCALE+1
      GO TO 1060
 1030 IF(ABS(DETERM)-R2)1040,1040,1060
 1040 DETERM=DETERM*R1
      ISCALE=ISCALE-1
      IF(ABS(DETERM)-R2)1050,1050,1060
 1050 DETERM=DETERM*R1
      ISCALE=ISCALE-1
 1060 IF(ABS(PIVOTI)-R1)1090,1070,1070
 1070 PIVOTI=PIVOTI/R1
      ISCALE=ISCALE+1
      IF(ABS(PIVOTI)-R1)320,1080,1080
 1080 PIVOTI=PIVOTI/R1
      ISCALE=ISCALE+1
      GO TO 320
 1090 IF(ABS(PIVOTI)-R2)2000,2000,320
 2000 PIVOTI=PIVOTI*R1
      ISCALE=ISCALE-1
      IF(ABS(PIVOTI)-R2)2010,2010,320
 2010 PIVOTI=PIVOTI*R1
      ISCALE=ISCALE-1
  320 DETERM=DETERM*PIVOTI
C
C     DIVIDE PIVOT ROW BY PIVOT ELEMENT
C
  330 A(ICOLUM,ICOLUM)=1.0
  340 DO 350 L=1,N
  350 A(ICOLUM,L)=A(ICOLUM,L)/PIVOT
  355 IF(M) 380, 380, 360
  360 DO 370 L=1,M
  370 B(ICOLUM,L)=B(ICOLUM,L)/PIVOT
C
C     REDUCE NON-PIVOT ROWS
C
  380 DO 550 L1=1,N
  390 IF(L1-ICOLUM) 400, 550, 400
  400 T=A(L1,ICOLUM)
  420 A(L1,ICOLUM)=0.0
  430 DO 450 L=1,N
  450 A(L1,L)=A(L1,L)-A(ICOLUM,L)*T
  455 IF(M) 550, 550, 460
  460 DO 500 L=1,M
  500 B(L1,L)=B(L1,L)-B(ICOLUM,L)*T
  550 CONTINUE
C
C     INTERCHANGE COLUMNS
C
  600 DO 710 I=1,N
  610 L=N+1-I
  620 IF (INDEX(L,1)-INDEX(L,2)) 630, 710, 630
  630 JROW=INDEX(L,1)
  640 JCOLUM=INDEX(L,2)
  650 DO 705 K=1,N
  660 SWAP=A(K,JROW)
  670 A(K,JROW)=A(K,JCOLUM)
  700 A(K,JCOLUM)=SWAP
  705 CONTINUE
  710 CONTINUE
  740 RETURN
      END
```

```
      SUBROUTINE FTLUP (X,Y,M,N,VARI,VARD)
C********DOCUMENT DATE 09-12-69    SUBROUTINE REVISED 07-07-69 *********
C*        MODIFICATION OF LIBRARY INTERPOLATION SUBROUTINE  FTLUP
      DIMENSION VARI(1),VARD(1),V(3),YY(2)
      DIMENSION II(43)
C*
C*     INITIALIZE ALL INTERVAL POINTERS TO -1.0   FOR MONOTONICITY CHECK
      DATA (II(J),J=1,43)/43*-1/
      MA=IABS(M)
C*
C*           ASSIGN INTERVAL POINTER FOR GIVEN VARI TABLE
C*     THE SAME POINTER WILL BE USED ON A GIVEN VARI TABLE EVERY TIME
      LI=MOD(LOCF(VARI(1)),43)+1
      I=II(LI)
      IF (I.GE.0) GO TO 10
      IF (N.LT.2) GO TO 10
C*
C*MONOTONICITY CHECK
      IF (VARI(2)-VARI(1)) 1,1,3
C* ERROR IN MONOTONICITY
    2 K=LOCF (VARI(1))
      PRINT 102,J,K,(VARI(J),J=1,N),(VARD(J),J=1,N)
  102 FORMAT (1H1,* TABLE BELOW OUT OF ORDER FOR FTLUP  AT POSITION  *
     1,I5,/* X TABLE IS STORED IN LOCATION *,O6,//(8G15.8))
      STOP
C* MONOTONIC DECREASING
    1 DO 5 J=2,N
      IF (VARI(J)-VARI(J-1))5,2,2
    5 CONTINUE
      GO TO 10
C* MONOTONIC INCREASING
    3 DO 6 J=2,N
      IF (VARI(J)-VARI(J-1))2,2,6
    6 CONTINUE
C*
C*INTERPOLATION
   10 IF (I.LE.0) I=1
      IF (I.GE.N) I=N-1
      IF (N.LE.1) GO TO 8
      IF (MA.NE.0) GO TO 99
C* ZERO ORDER
    8 Y=VARD(1)
      GO TO 800
C* LOCATE I INTERVAL (X(I).LE.X.LT.X(I+1))
   99 IF ((VARI(I)-X)*(VARI(I+1)-X)) 61,61,40
C* IN GIVES DIRECTION FOR SEARCH OF INTERVALS
   40 IN=SIGN(1.0,(VARI(I+1)-VARI(I))*(X-VARI(I)))
C* IF X OUTSIDE ENDPOINTS, EXTRAPOLATE FROM END INTERVAL
   41 IF ((I+IN).LE.0) GO TO 61
      IF ((I+IN).GE.N) GO TO 61
      I=I+IN
      IF ((VARI(I)-X)*(VARI(I+1)-X)) 61,61,41
   61 IF (MA.EQ.2) GO TO 200
C*
C*FIRST ORDER
      Y=(VARD(I)*(VARI(I+1)-X)-VARD(I+1)*(VARI(I)-X))/(VARI(I+1)-VARI(I)
     1  )
      GO TO 800
C*
C*SECOND ORDER
```

```
  200 IF (N.EQ.2) GO TO 2
      IF (I.EQ.(N-1)) GO TO 209
      IF (I.EQ.1) GO TO 201
C* PICK THIRD POINT
      SK= VARI(I+1)-VARI(I)
      IF ((SK*(X-VARI(I-1))).LT.(SK*(VARI(I+2)-X))) GO TO 209
  201 L=I
      GO TO 702
  209 L=I-1
  702 V(1)=VARI(L)-X
      V(2)=VARI(L+1)-X
      V(3)=VARI(L+2)-X
      YY(1)=(VARD(L)*V(2)-VARD(L+1)*V(1))/(VARI(L+1)-VARI(L))
      YY(2)=(VARD(L+1)*V(3)-VARD(L+2)*V(2))/(VARI(L+2)-VARI(L+1))
      Y=(YY(1)*V(3)-YY(2)*V(1))/(VARI(L+2)-VARI(L))
  800 II(LI)=I
      RETURN
      END
```

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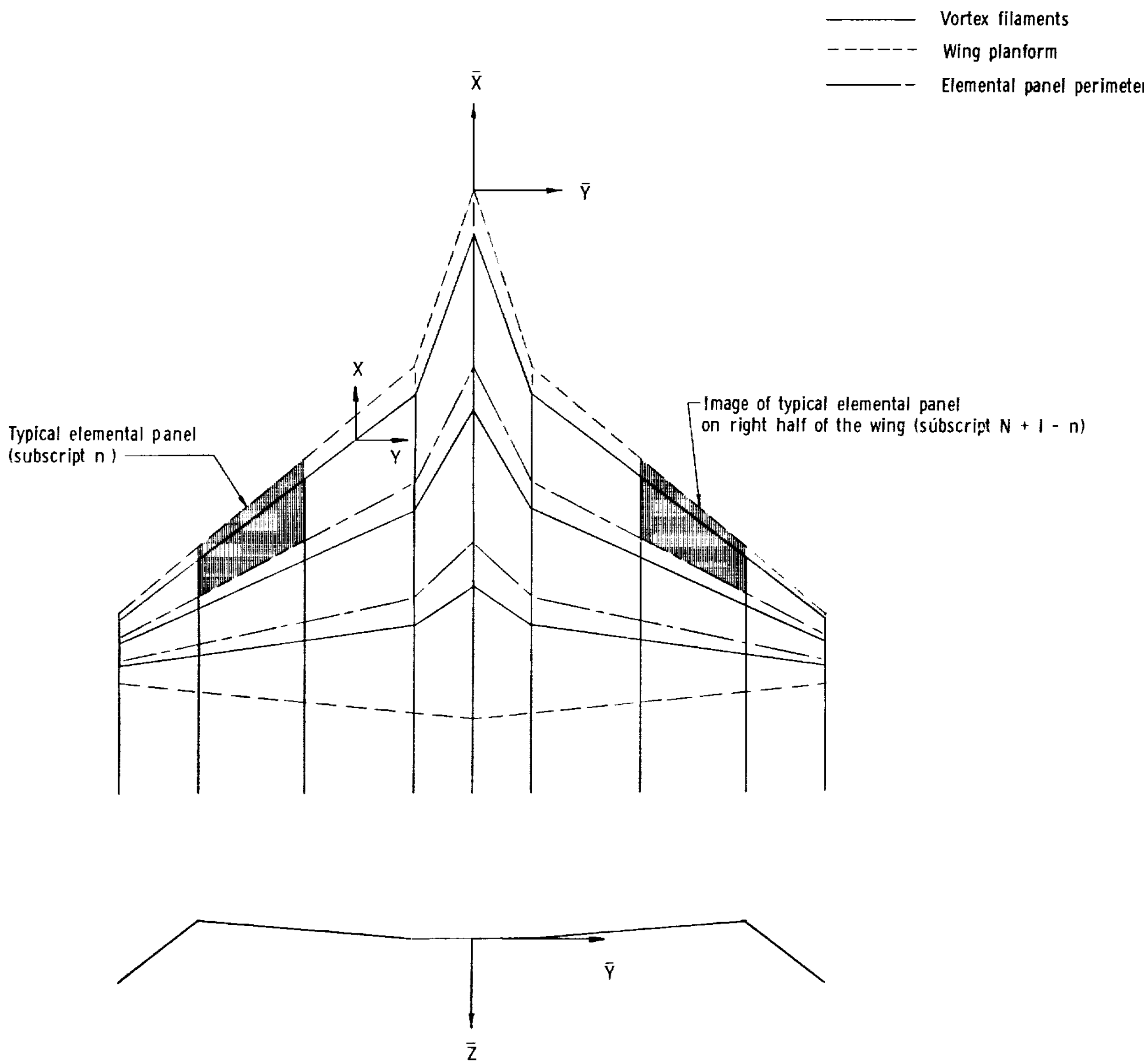


Figure 1.- General layout of axis systems, elemental panels, and horseshoe vortices for a typical wing planform.

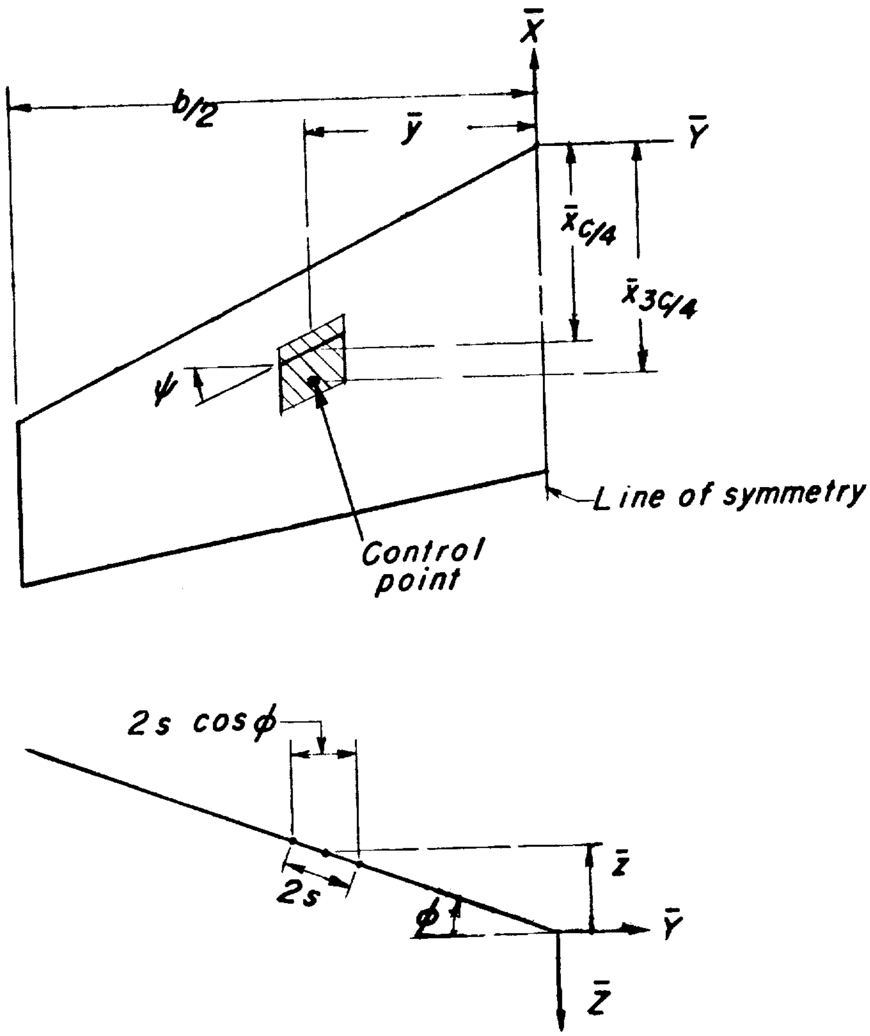


Figure 2.- Variables used to describe the geometry of an elemental panel.

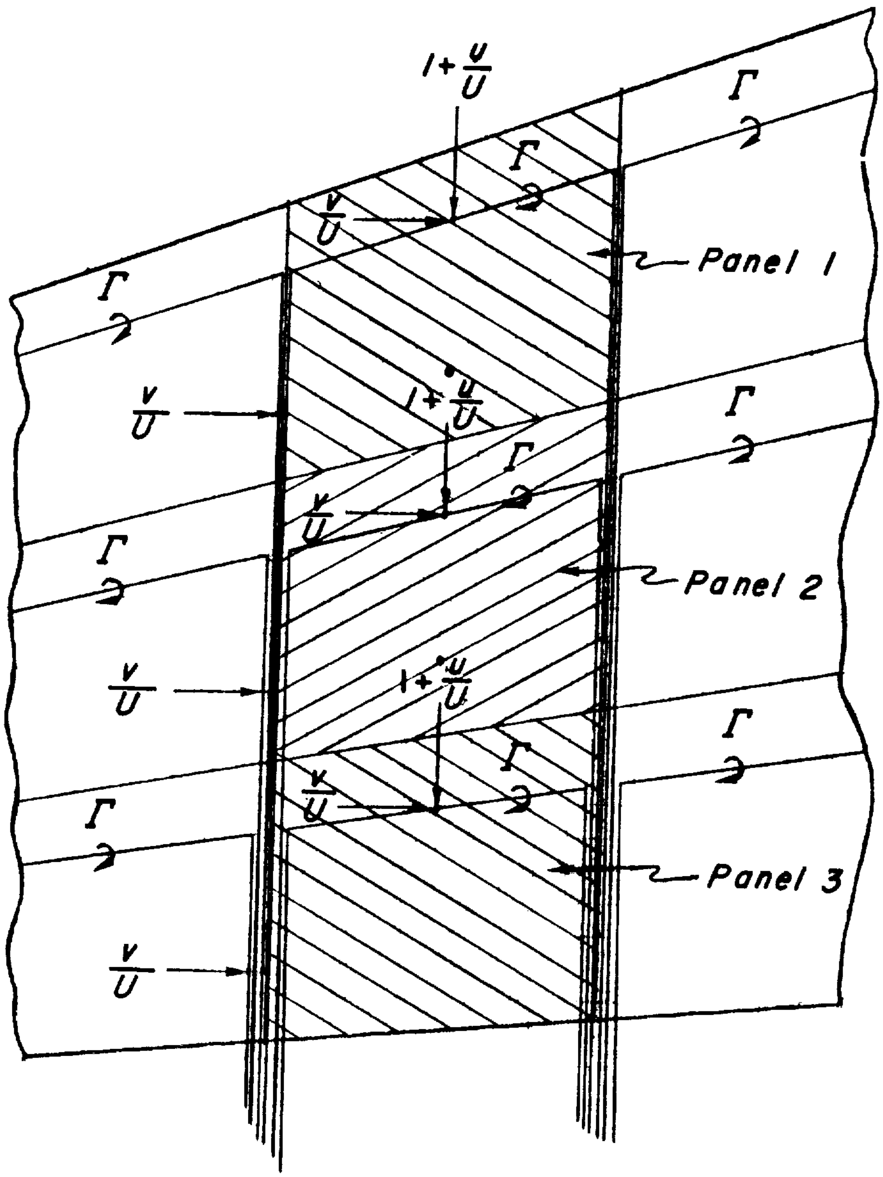


Figure 3.- This detailed sketch of a chordwise row of horseshoe vortices illustrates the velocities and circulations used to compute lift and pitching moment on the elemental panels of a wing with dihedral. Note that the velocity terms and circulations which are shown with each horseshoe vortex are different. (See Part III, Section 1 for discussion.)

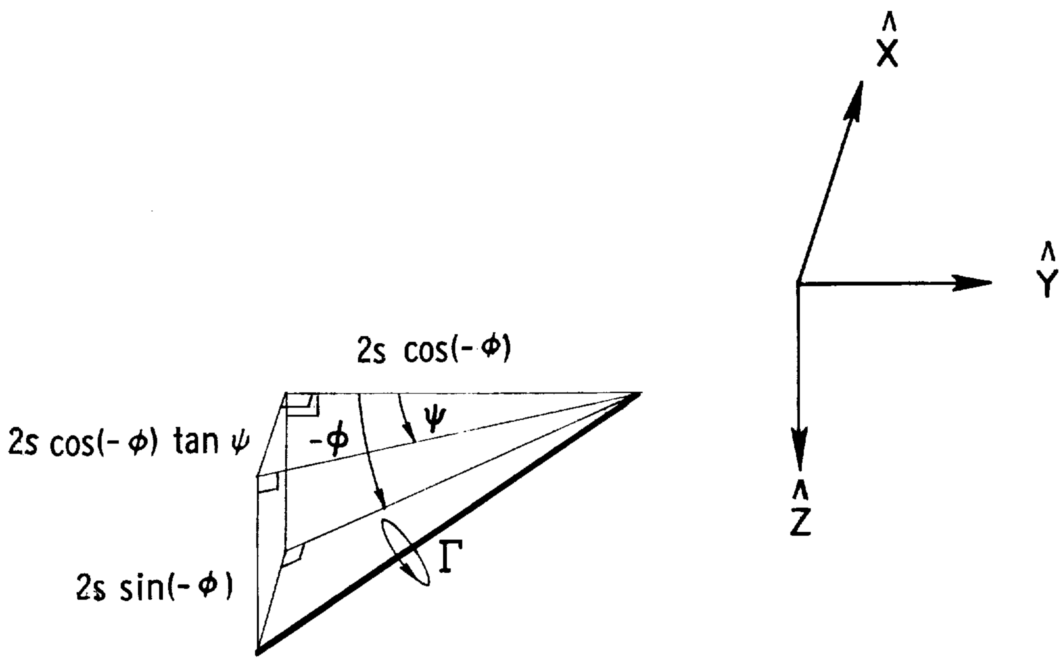


Figure 4.- Spanwise bound vortex filament at an arbitrary orientation in the flow.

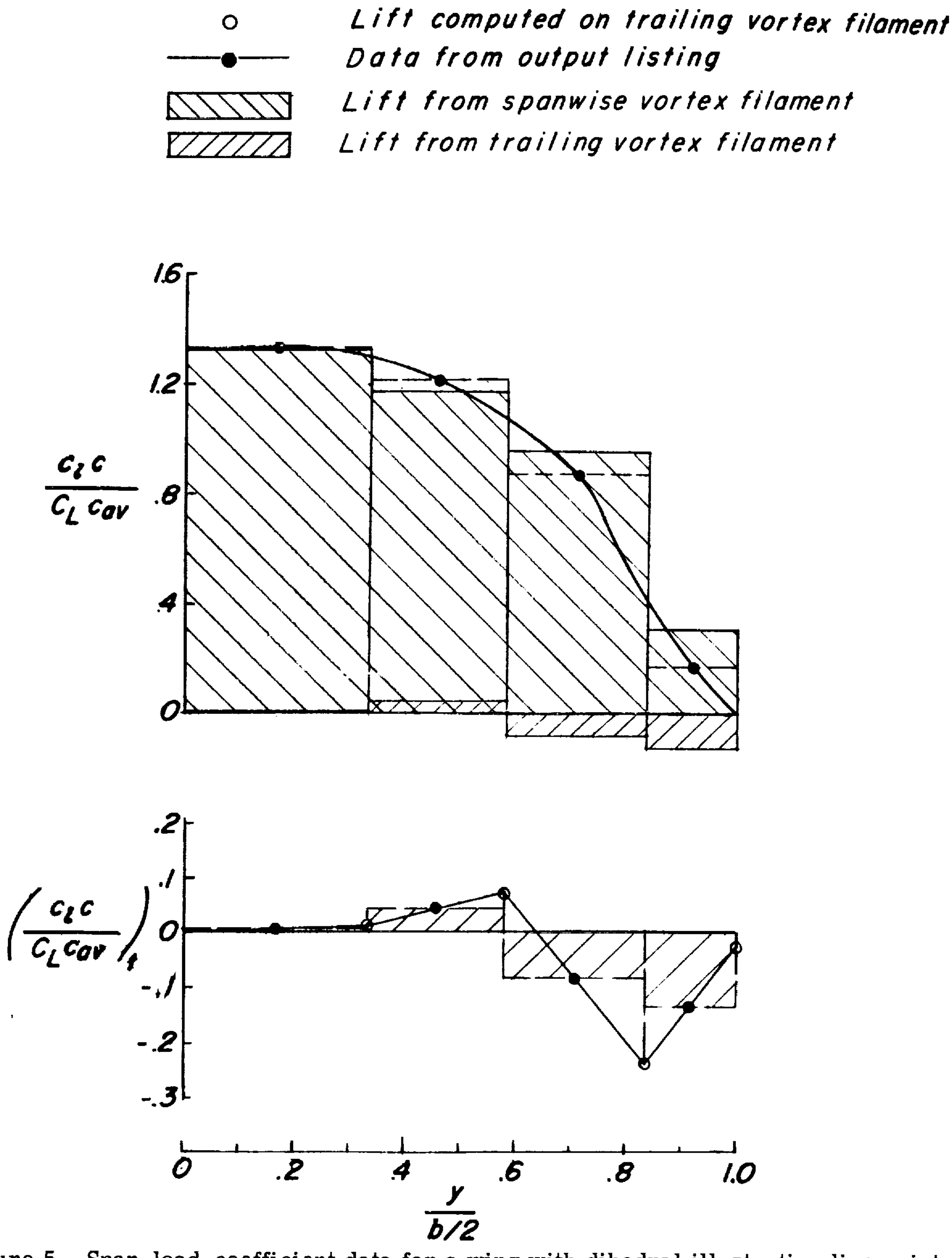


Figure 5.- Span-load-coefficient data for a wing with dihedral illustrating linear interpolation of lift generated along trailing vortex filaments and the combination of these interpolated values with lift generated along spanwise filament of vorticity to obtain final span load distribution.

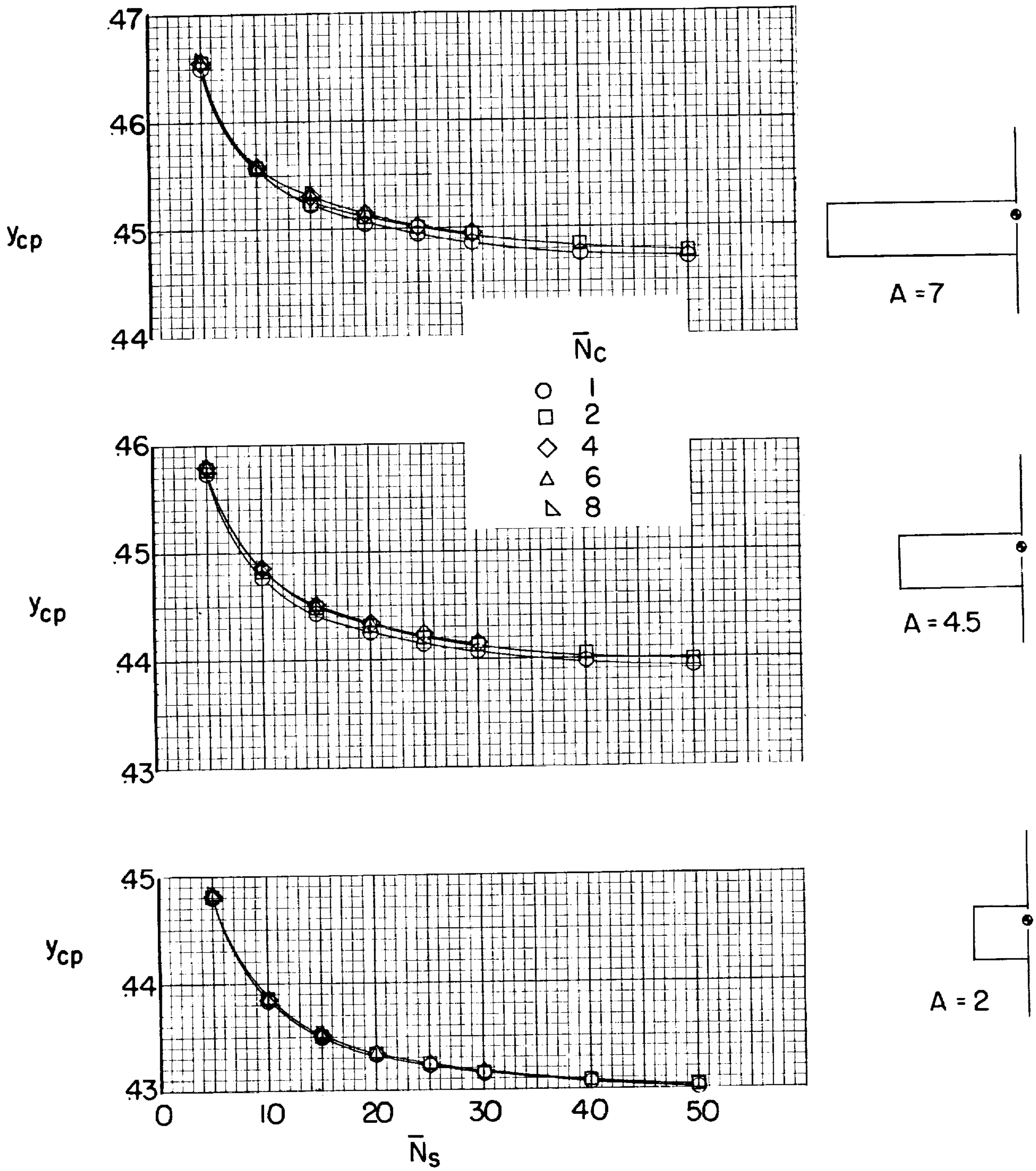
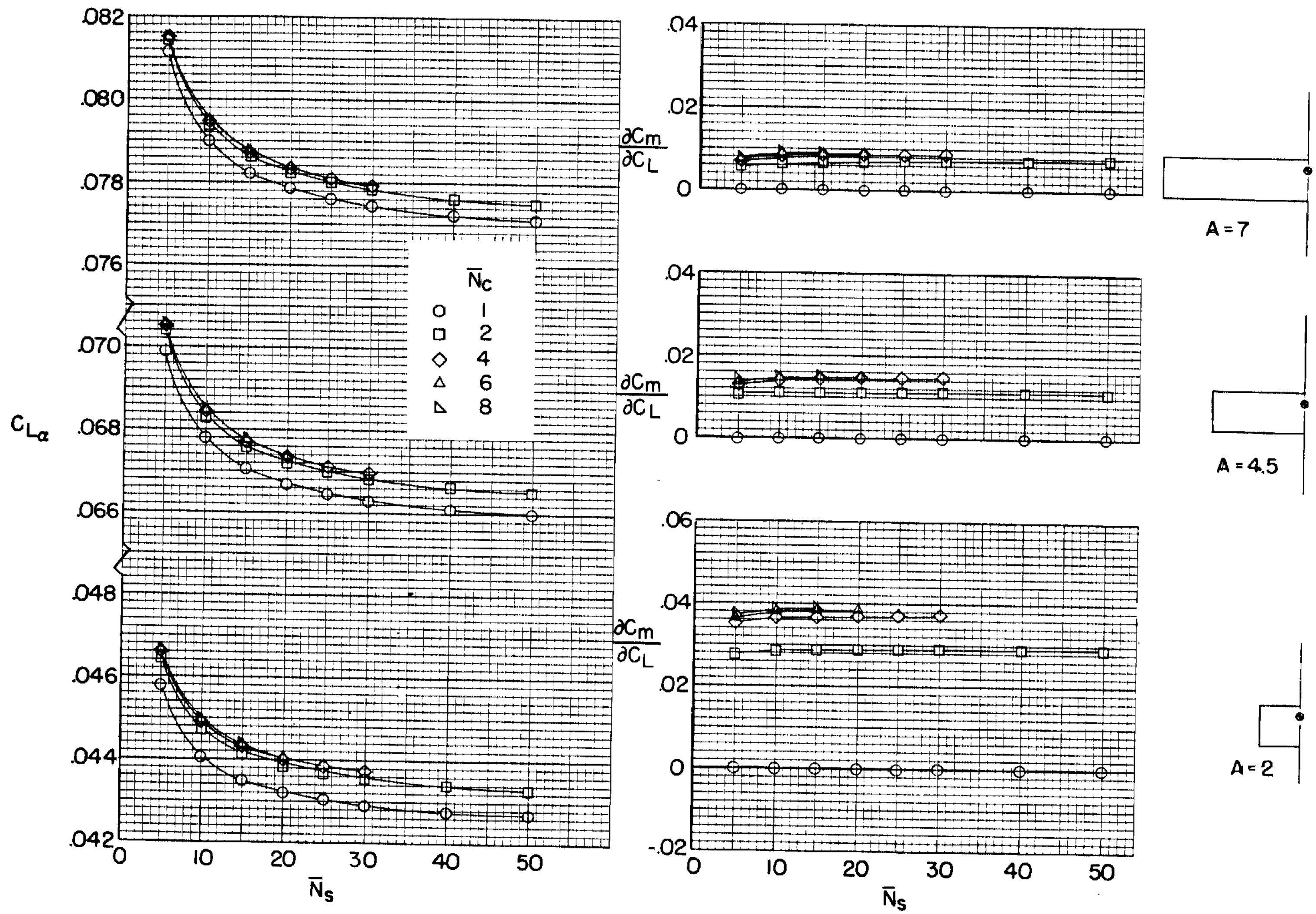
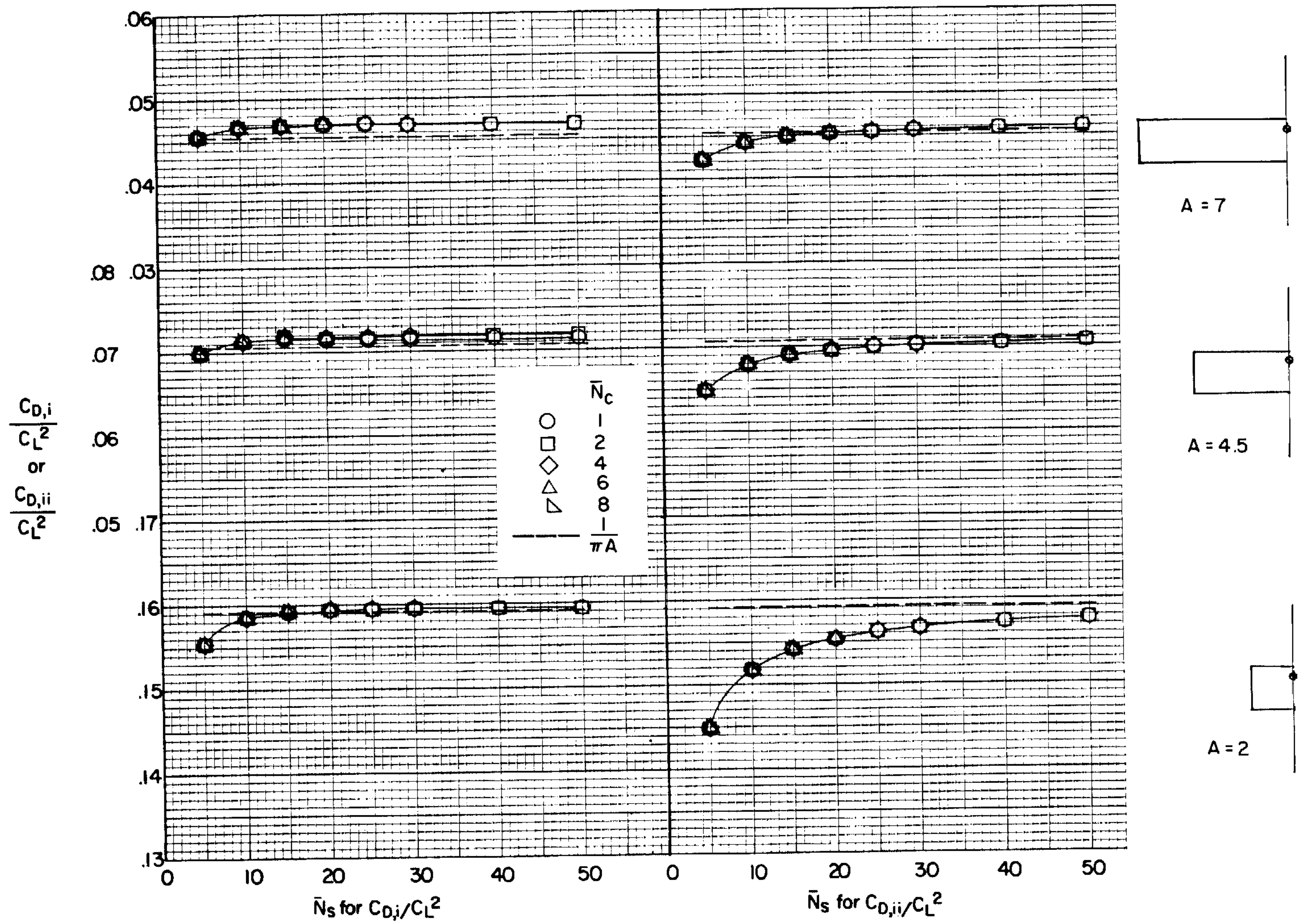


Figure 6.- Effect of vortex-lattice arrangement on y_{cp} for rectangular wings at $M_{\infty} = 0$.



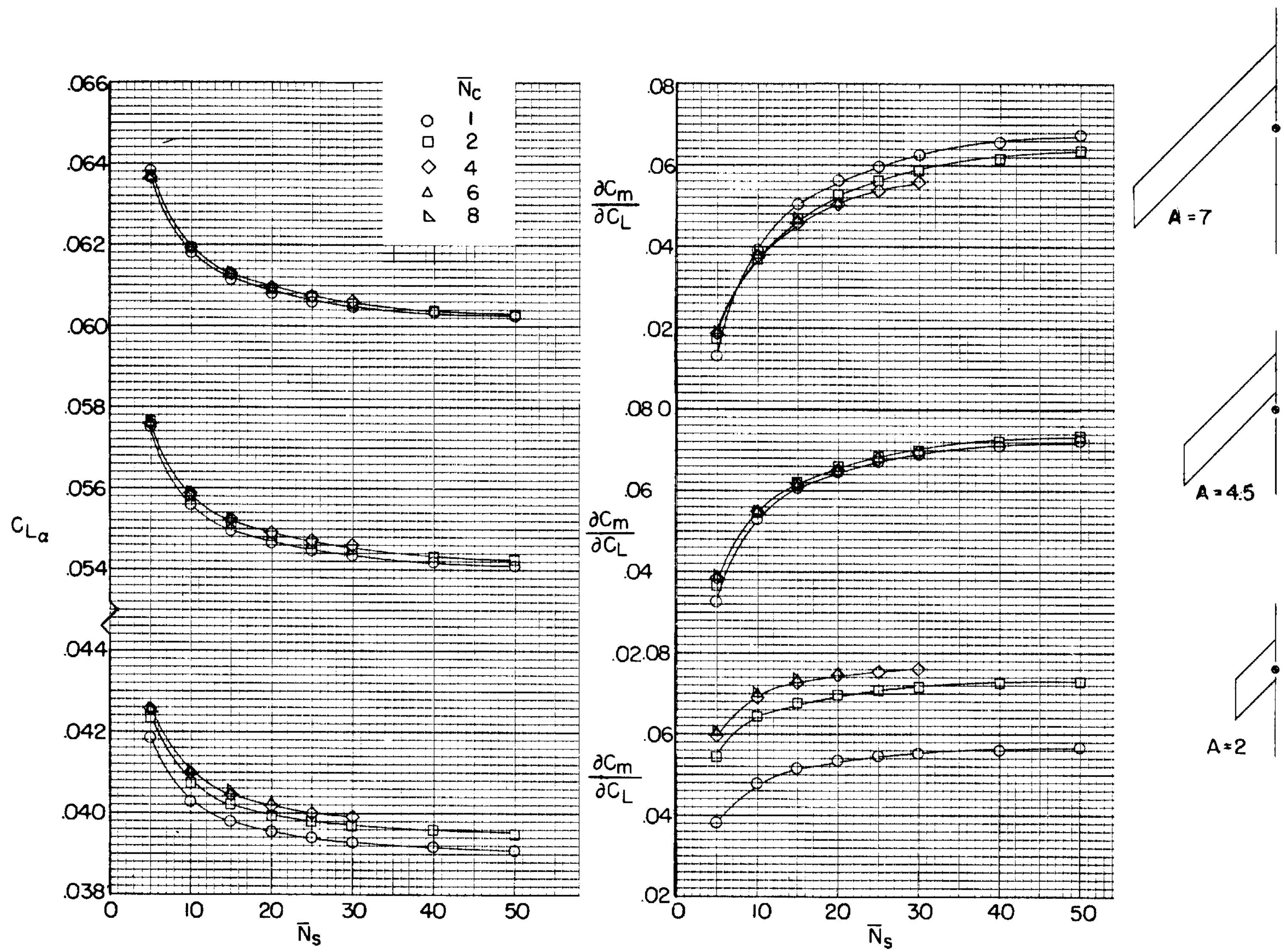
(a) C_{L_α} and $\partial C_m/\partial C_L$.

Figure 7.- Effect of vortex-lattice arrangement for rectangular wings at $M_\infty = 0$.



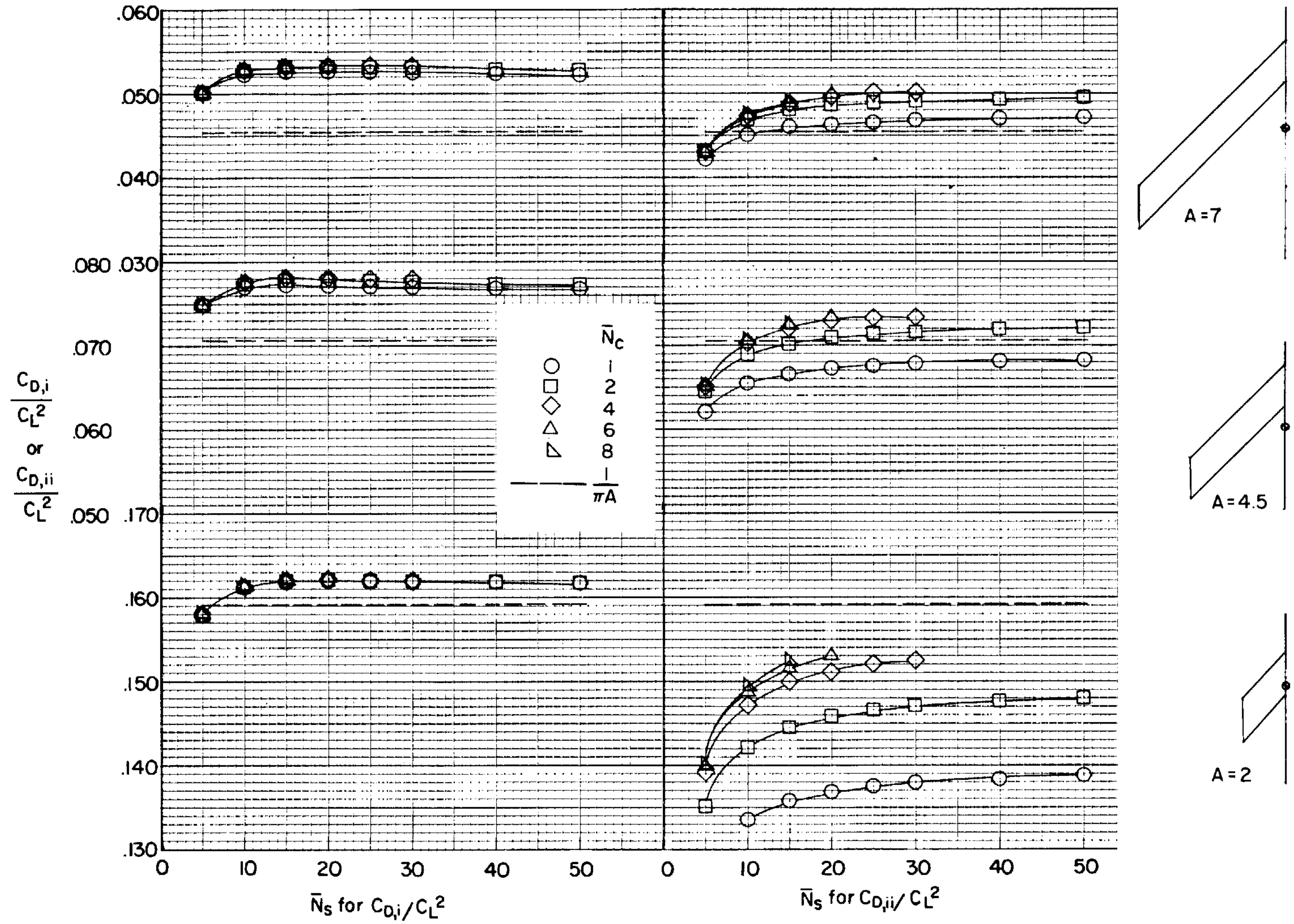
(b) $C_{D,i}/C_L^{\,2}$ and $C_{D,ii}/C_L^{\,2}$.

Figure 7.- Concluded.



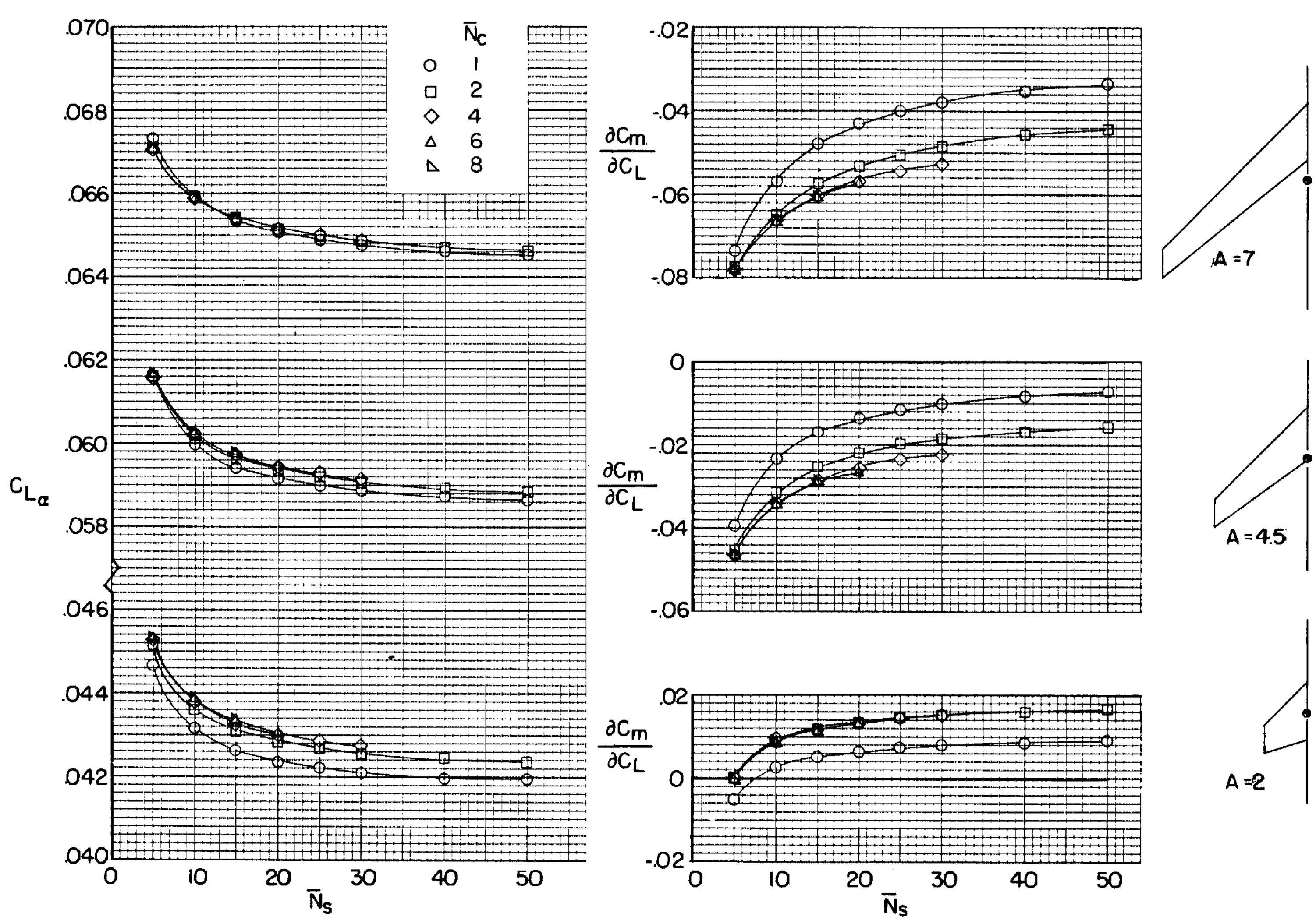
(a) C_{L_α} and $\partial C_m / \partial C_L$.

Figure 8.- Effect of vortex-lattice arrangement for wings with a leading-edge sweep angle of 45° and a taper ratio of 1.0 at $M_\infty = 0$.



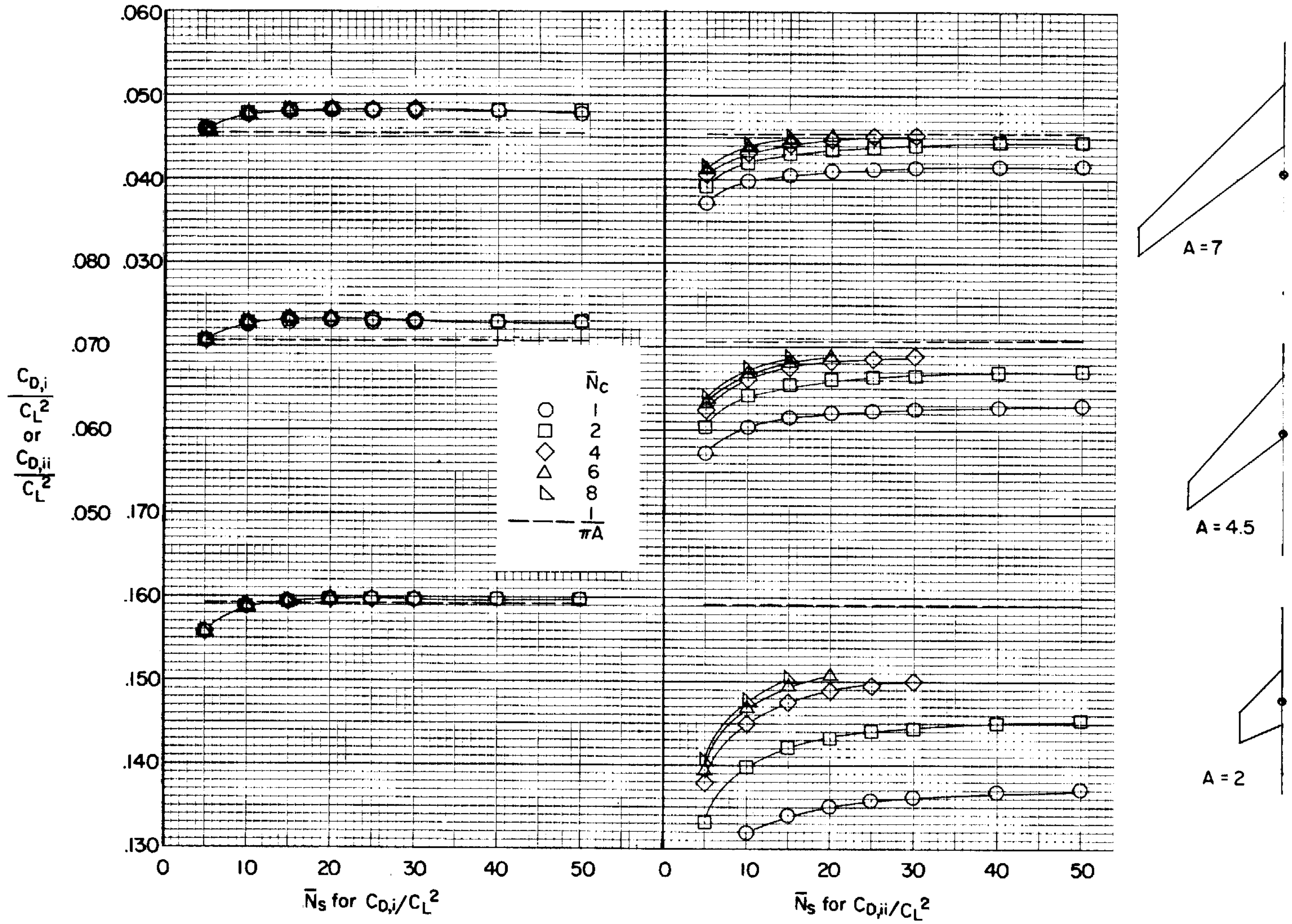
(b) $C_{D,i}/C_L^2$ and $C_{D,ii}/C_L^2$.

Figure 8.- Concluded.



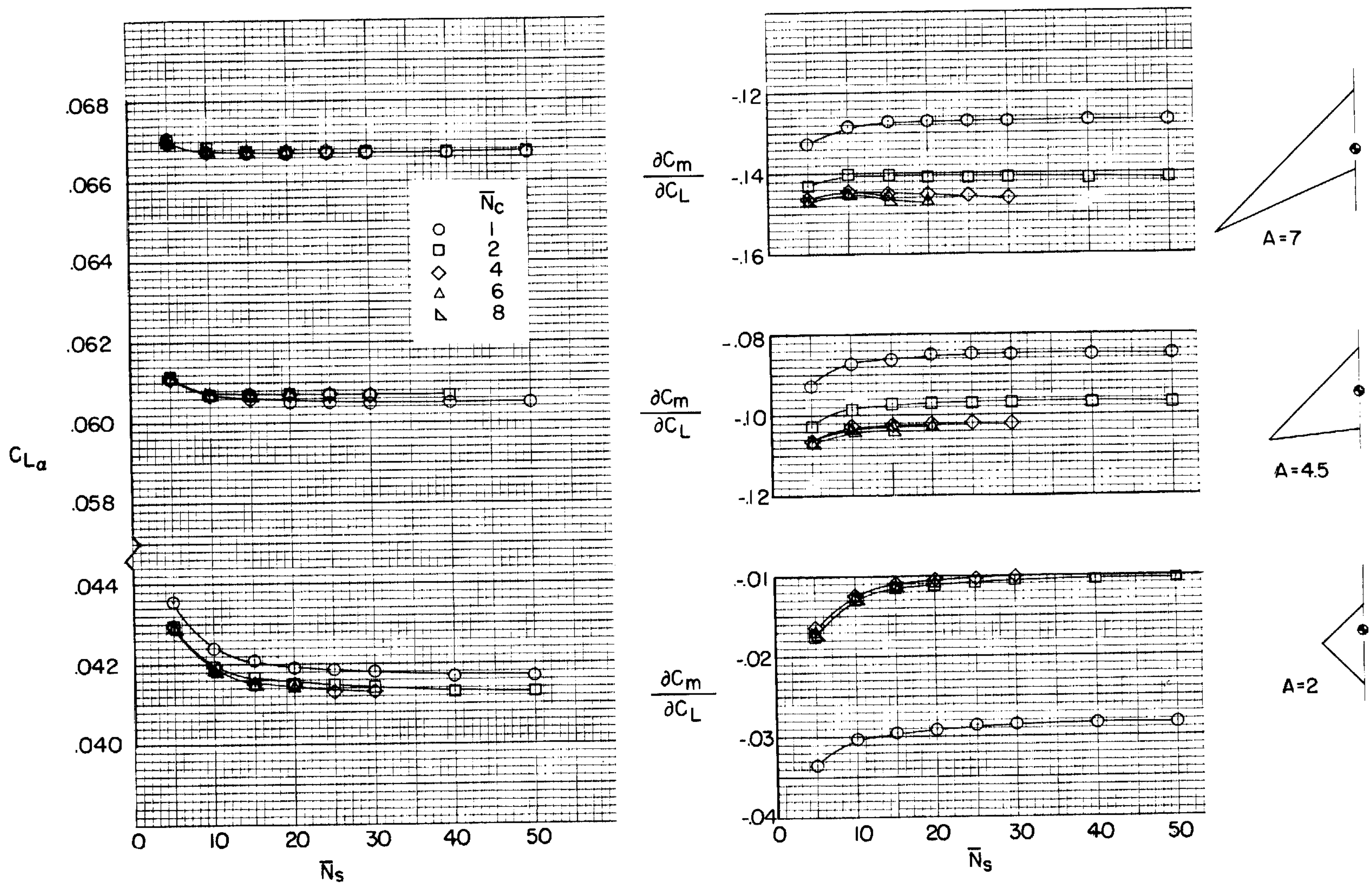
(a) C_{L_α} and $\partial C_m / \partial C_L$.

Figure 9.- Effect of vortex-lattice arrangement for wings with a leading-edge sweep angle of 45^0 and a taper ratio of 0.5 at $M_\infty = 0$.



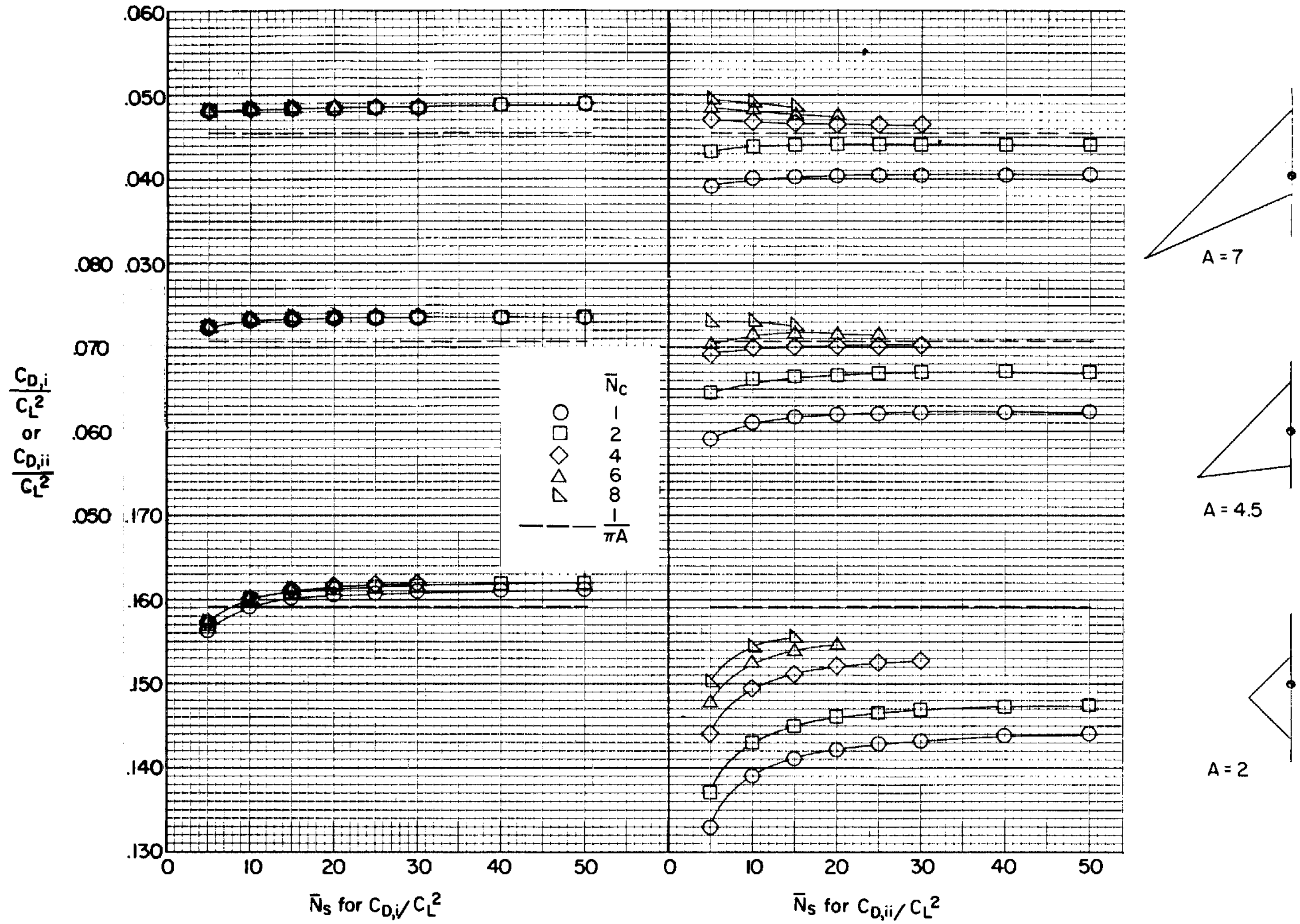
(b) $C_{D,i}/C_L^2$ and $C_{D,ii}/C_L^2$.

Figure 9.- Concluded.



(a) C_{L_α} and $\partial C_m / \partial C_L$.

Figure 10.- Effect of vortex-lattice arrangement for wings with a leading-edge sweep angle of 45° and a taper ratio of 0 at $M_\infty = 0$.



(b) $C_{D,i}/C_L^2$ and $C_{D,ii}/C_L^2$.

Figure 10.- Concluded.

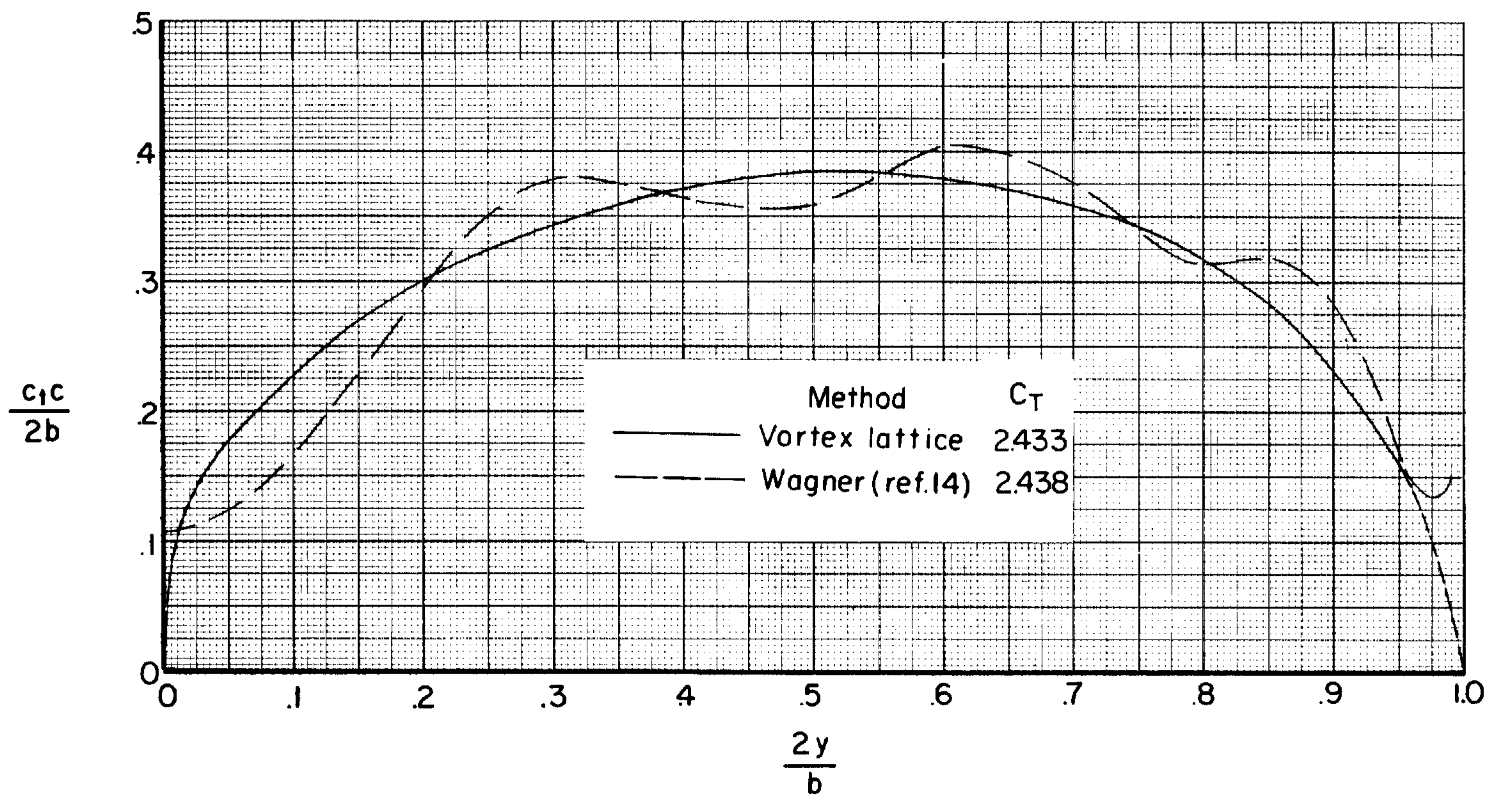


Figure 11.- Variation of nondimensional section leading-edge thrust-coefficient term for an $A = 4$ delta wing at $M_\infty = 0$ and $\alpha = 1$ radian. Vortex-lattice results were computed with $\overline{N}_c = 10$ and $\overline{N}_s = 12$.

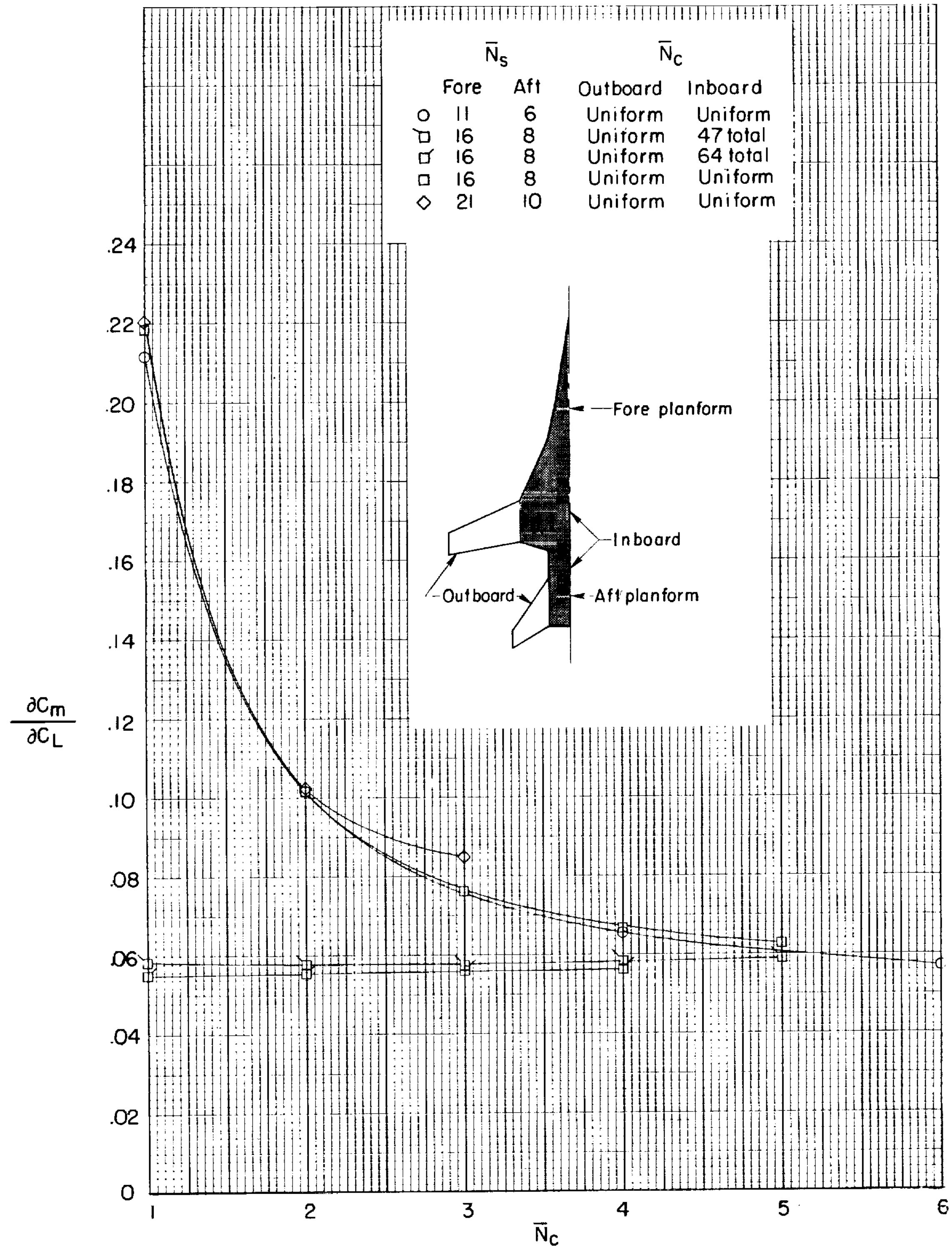


Figure 12.- Effect of vortex-lattice arrangement on $\partial C_m/\partial C_L$ for a wing-body-tail combination at $M_\infty = 0$.